57TH CONGRESS, 1st Session. | HOUSE OF REPRESENTATIVES. | DOCUMENT No. 5.

ANNUAL REPORTS

OF THE

DEPARTMENT OF THE INTERIOR

FOR THE

FISCAL YEAR ENDED JUNE 30, 1901.

TWENTY-SECOND ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY,

CHARLES D. WALCOTT, DIRECTOR.

PART II.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1901.

Poor Quality Source Document

The following document images have been scanned from the best available source copy.

To view the actual hard copy, contact the Superfund Records Center at (303) 312-6473.

THE ORE DEPOSITS OF THE RICO MOUNTAINS COLORADO

BY

FREDERICK LESLIE RANSOME

CONTENTS.

ILLUSTRATIONS.

THE ORE DEPOSITS OF THE RICO MOUNTAINS, COLORADO.

By F. L. Ransome.

INTRODUCTION.

Field work in the Rico district was begun on the 1st of July, 1900, with Mr. Alfred Mayer Rock as field assistant, and was brought to a close on the 18th of August of the same year. It was found that work in the larger mines had practically ceased, and that leasing on a small scale and prospecting were the only surviving forms of mining activity. But against this decided disadvantage in a study of the ore deposits were to be set off some factors of direct gain. In 1896, Mr. C. W. Purington, then of the United States Geological Survey, visited the region and made a brief investigation of the ore deposits. The results of his reconnaissance were never published. They indicated that the interest and complexity of the phenomena there displayed demanded a better and larger-scale topographic map than was then available, as well as a comprehensive investigation of the geology of the region. This map was made, and in 1898 Mr. G. W. Tower was detailed to make a thorough study of the ore deposits of the Rico Mountains in connection with the geological work of Messrs. Cross and Spencer. Mr. Tower subsequently severed his connection with this Survey, and his manuscript report was never published.

The notes and manuscripts of Messrs. Purington and Tower, as well as their collections, were placed at my disposal and have been employed to supplement my own observations wherever this appeared necessary. Where their material has been so used it has been credited to its source. The main usefulness of their notes, however, has been to afford starting points from which to plan various lines of investigation in the field. To Mr. Tower I am particularly indebted for a complete set of tracings of such mine maps as could be obtained at the time his work was done and for an excellent collection of the ores of the district. The possession of these has resulted in a considerable saving of time and labor.

The literature of the Rico district is not extensive. A paper by John B. Farish[1] on the ore deposits of Newman Hill and a later one

[1] On the ore deposits of Newman Hill, near Rico, Colo.: Proc. Colo. Sci. Soc., Vol. IV, 1892, pp. 151-164.

by T. A. Rickard[1] on the Enterprise mine are important contributions and will be frequently referred to in the following pages. The latest and most comprehensive work, however, is the report of Messrs. Whitman Cross and Arthur C. Spencer[2] on the geology of the Rico region. A knowledge of the essential results of their investigation and interpretation of the general geological structure and history is necessary for a proper understanding of the following pages. The present paper is, in fact, a supplement and sequel to their report.

Of the mining men of this district it is difficult to speak in terms of merely formal acknowledgment. An experience of some years in Western mining towns has failed to discover such hospitality, natural courtesy, and readiness to further scientific investigation by all means in their power, as was shown, without any exception, by the men of Rico.

GEOGRAPHY.

The region covered by the Rico special map[3] and treated in this report lies in southwestern Colorado, between longitude 107° 58′ 37″ and 108° 5′ 39″ west and latitude 37° 40′ and 37° 44′ 39″ north. Its area is approximately 35 square miles, and its general position is shown by the accompanying index map (fig. 39). Rico, a town of a few hundred inhabitants and the county seat of Dolores County, lies nearly in the center of the district, on the Dolores River, which traverses the area from north to south. The Rio Grande Southern Railroad connects the town with the Denver and Rio Grande system at Durango on the south and at Ridgway on the north.

The mining district is nearly coextensive with the isolated group of peaks which have been called the Rico Mountains and which constitute an uplift distinct from the Mount Wilson group on the north, the San Juan Mountains on the northeast, and the La Plata Mountains on the south. On the west the Rico Mountains subside into the slightly inclined, dissected plateaus which stretch away into Utah.

HISTORY.

Records of the discovery and early development of the Rico ore bodies are fragmentary and often conflicting. The following data are drawn largely from an article entitled "The early trail blazers," which was published in the Rico News of June, 1892, and which was brought to my attention by Mr. G. W. Tower. The events recorded in this sketch, which bears evidence of careful preparation, have been

[1] The Enterprise mine, Rico, Colo.: Trans. Am. Inst. Mining Eng., Vol. XXVI, 1896, pp. 906-960. Also published, in part, under title Vein structure in the Enterprise mine: Proc. Colo. Sci. Soc., Vol. V, 1894-96, pp. 123-130.

[2] Geology of the Rico Mountains: Twenty-first Ann. Rept. U. S. Geol. Survey, 1899-1900, Pt. II, pp. 7-165.

[3] Cross and Spencer: loc. cit., Pl. XXII.

verified as far as possible by comparison with other less extended references to the region, including Bancroft's History of Colorado, Frank Fossett's Colorado (the second edition of which was published at New York in 1880), and T. A. Rickard's Enterprise Mine.

It is possible that some of the early Spanish explorers found their

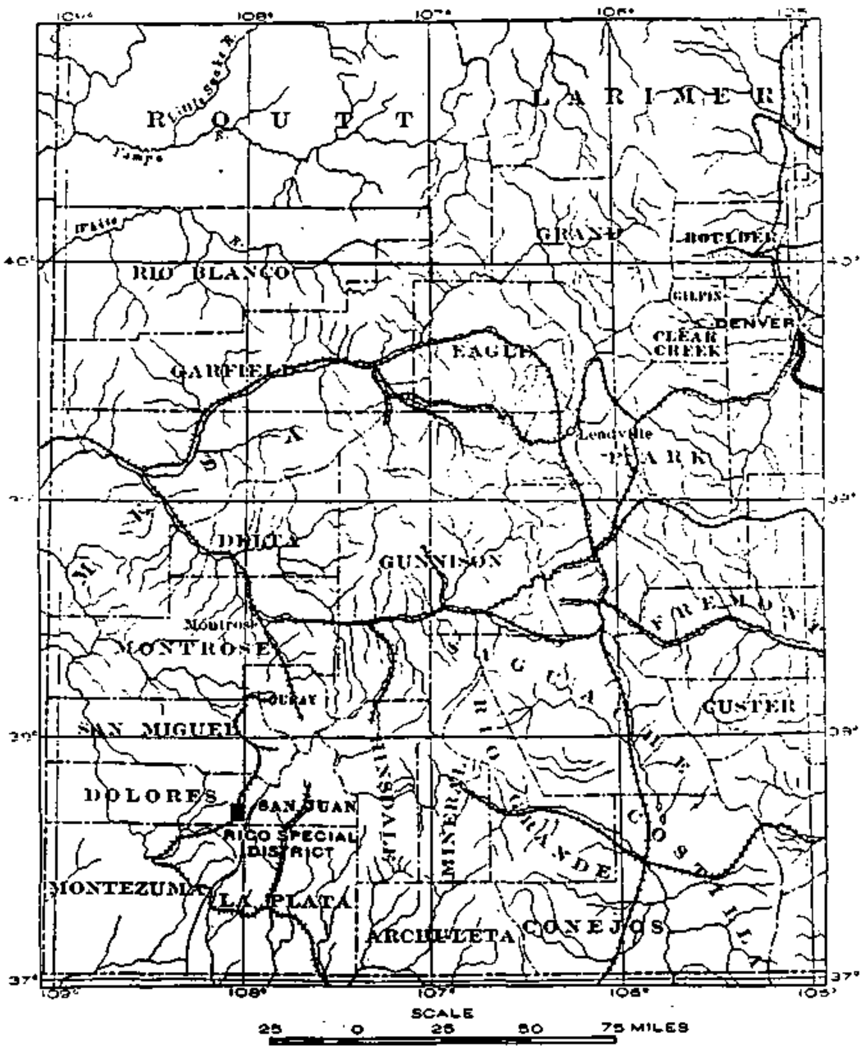


Fig. 39.—Index map showing position of Rico district.

way up to the valley of the Dolores River, but the first party of white men known to have penetrated this region consisted of about 60 trappers from St. Louis, under the leadership of William G. Walton. This party set out from the trading post of Taos, N. Mex., and spent the summer of 1833 along the Dolores River and in camp near Trout Lake, about 13 miles northeast of the present site of Rico.

In 1861 Lieutenant Howard and other members of John Baker's expedition into the San Juan region made their way over the mountains from the east and prospected the Dolores River, afterwards rejoining the main party at Bakers Park, where the town of Silverton now stands.

Five years later a party from Arizona, under Colonel Nash, following the Santa Fe and Salt Lake trail, reached the Big Bend of the Dolores (where the town of Dolores now stands), and explored the river to its source. Thence they crossed the divide to Trout Lake and proceeded down the San Miguel River.

In 1869 Sheldon Shafer and Joseph Fearheiler reached the site of Rico on their way from Santa Fe to Montana. They were well provided with tools and provisions and, struck by the indications of mineral wealth which the region afforded, decided to thoroughly prospect the district. They built a cabin on Silver Creek, near the spot where the South Park mine was afterwards opened, and located, in July, 1869, a claim which they called the Pioneer, a name that afterwards became the official designation of the mining district. It covered portions of what are now the Shamrock, Smuggler, and Riverside claims. They also made a location which they named the Nigger Baby, on account of the abundant black oxide of manganese found in the vein. Although this claim afterwards became part of the Phœnix mine, the name was perpetuated as Nigger Baby Hill. In the autumn of 1869 they built a more substantial cabin near where the Rico State Bank now stands, and worked on the Pioneer claim through the winter.

In 1870 R. C. Darling, engaged in surveying the boundaries of the Ute Indian Reservation, passed up the Dolores on his way to Mount Sneffels. He found Fearheiler and Shafer at work, located some claims near them, and proceeded on his way up stream. His name survives in Darling Ridge, one of the spurs of Expectation Mountain.

During the same year "Gus" Begole, John Echols, Dempsey Reese, and "Pony" Whittemore came into the district from New Mexico and discovered the Aztec and other lodes. On the approach of winter all of the prospectors relinquished their work and left the district. Fearheiler never returned, being killed by Indians on his way to Fort Defiance.

Apparently none of the adventurous prospectors came back to their claims in the following summer, but in 1872, Darling, who had succeeded in interesting some army officers and capitalists from Washington, D. C., in the resources of the region, led a large party into the Pioneer district from Santa Fe. They carried with them a few lengths of board from which they constructed molds for adobe bricks, and of these they erected a Mexican smelting furnace. Ore was extracted from what are now the Atlantic Cable, Aztec, Phœnix, and Yellow Jacket claims, and three small bars of bullion were produced in this furnace. The adobe, however, was not sufficiently refractory, and the furnace soon became useless. Discouraged by their failure and by the low grade of the bullion, the claims were abandoned on the approach of winter and the party returned to Santa Fe.

Two years later, members of the Hayden survey mapped the region and gave many of the existing names to the more prominent topographical features.

Prospecting was again resumed in the Pioneer district in 1877, and in 1878 became active through the energy of John Glasgow, "Sandy" Campbell, David Swickhimer, and others. The Atlantic Cable, Blackhawk, Hope, Cross, Grand View, Major, Phœnix, Yellow Jacket, Pelican, Aztec, and Columbia claims were all located in 1878, but, as usual, work was abandoned when the winter snows whitened the surrounding peaks.

In the spring of 1879, rich oxidized silver ore was discovered on Nigger Baby Hill and a rush to the district from the neighboring camps followed. Several claims on Nigger Baby Hill were sold to the Grand View Mining Company, in which Senator Jones and John W. Mackay, well known for their operations on the Comstock, were prominent stockholders. Ore was also found in the Chestnut vein, on Newman Hill, and a small shipment was made to Swansea.

The beginnings of a settlement sprang up. The town site was surveyed and divided into lots, and E. A. Robinson became justice of the peace. The first newspaper, the Dolores News, appeared on August 21, the first seven numbers being printed in Silverton. A post-office was opened and the name Rico was given to the growing town.

The Grand View smelter was begun in 1880, the machinery coming from the railway terminus at Alamosa by wagons to Mancos, and thence over the now abandoned road which reached the Dolores River by the dreaded Bear Creek Hill, 12 miles south of Rico. The freight from Alamosa was about $300 per ton. Late in the autumn the smelter began producing bullion. This same year saw the discovery of the Johnny Bull ore body.

The year 1881 is notable for a punitive expedition against a party of Utes, who were overtaken near the La Sal Mountains and defeated, with considerable loss of life on both sides.

The following spring the Rico Mining and Smelting Company began the erection of a second smelter in the southern end of town, and the Newman group of mines was sold to the Marrs Consolidated Mining Company for $175,000.

In 1883 the finding of ore in the South Park mine, on Silver Creek, led to active prospecting along this stream.

In 1884 the Rico smelter was purchased and repaired by the Pasadena Company, and was operated as a custom plant for nearly two years.

As early as 1881 David Swickhimer, Patrick Cain, and John Gault began a shaft on the Enterprise claim on Newman Hill, but subsequently sold their property for a few hundred dollars' worth of lumber. But the success of Larned and Hackett in following the veins in the Chestnut and Swansea claims led Swickhimer to repurchase a controlling interest in the Enterprise, and in October, 1887, he struck ore at a depth of 262 feet. This was the first discovery of the so-called "contact" or blanket ore, and the shaft had fortunately cut the edge of the largest and richest ore body ever found on Newman Hill.

The result of Swickhimer's discovery was to infuse new life into the district. Large bodies of ore were found in the Blackhawk, Logan, and Rico-Aspen mines, and the future of Rico looked brighter than ever before.

The Enterprise group was sold in 1890 to a Pittsburg company, and the same year saw the advent of the Rio Grande Southern Railroad. Litigation sprang up between the Enterprise and Rico-Aspen companies, but production went on, and when the suit was finally won by the Enterprise the ore in the disputed territory had been extracted, largely by the Rico-Aspen Company.

Since 1895 the output of the Pioneer district has decreased. The large bodies of rich "contact" ore have been mined out and many of the veins have been worked down to a depth at which the ore no longer pays for shipment. Masses of ore often proved to be curiously limited, owing to various conditions that are characteristic of the region, and that will be described in the following pages. The declining price of silver has had a depressing effect on this, as on other districts, where this metal forms a large part of the output. But nearly all the important ore bodies formerly exploited were sufficiently rich to be workable to-day had they not been exhausted.

In the year 1900 the only ore being shipped from the district was an occasional carload taken out by leasers working small areas of unexplored ground in the larger mines. Whether the present inactivity is final or not is a question that can not be decided offhand. Prosperity and depression, following each other in rhythmic procession, are the lot of many mining districts, and it is often difficult to distinguish a state of quiescence from one of extinction.

Whatever the economic future of the Pioneer district may be, the modes of occurrence of its ores present many problems of unusual and living interest. After a consideration of these, the question of a possible revival of mining activity may be more intelligently answered.

PRODUCTION.

The total production of the Pioneer mining district can be only roughly estimated. According to the reports of the Director of the Mint, the output from 1879 to the end of 1900 has been about 73,000 ounces of gold and 9,000,000 ounces of silver. It is estimated that the value of the entire output, including the base metals, lies somewhere between $8,000,000 and $10,000,000. By far the greater part of this has been silver.

CLIMATE AND VEGETATION.

The climate of Rico can be described only in general terms, as there are no meteorological data available. The winters are less severe than at Silverton, which lies in the heart of the neighboring San Juan Mountains, but are nevertheless characterized by heavy snows, which may begin in September or October. As most of the Rico mines are below timber line, the danger from snowslides is less than in the higher and more rugged regions of the San Juan. The summers, as might be expected at altitudes ranging from about 8,500 to 12,600 feet, are pleasantly cool, and in normal years thunder showers are of frequent occurrence in July and August.

The mountain slopes are well covered with aspens, spruce, and balsam fir up to a timber line varying from 11,500 to 12,000 feet in altitude. The aspens are particularly abundant on the lower slopes, often forming a luxuriant second growth upon the site of earlier aspen woods which have been cut away. Both spruces and aspens are used for mine timbering, the aspens being valuable on account of their proximity to most of the mines and the rapidity with which new trees spring up to take the place of those felled.

Among the smaller shrubs, the wild raspberry flourishes abundantly and becomes laden with fruit in August or September, while through early summer the usual wild flowers common in Colorado at these altitudes bloom in gay profusion.

TOPOGRAPHY.

As fully described by Cross and Spencer in their paper already referred to, the compact cluster of peaks known as the Rico Mountains is the remains of a much dissected structural dome rising above the Dolores Plateau. To the west this plateau, which near the Rico Mountains has an elevation of about 9,400 feet, stretches away into Utah. On the north, east, and south the original horizontal plateau structure has been somewhat modified by the elevation of the Wilson, San Juan, and La Plata mountain groups, and of the Rico Mountains themselves. The Dolores River crosses the Rico dome from north to south, and through erosion by this stream and its tributaries the Rico dome, traversed by numerous fault fissures, has been carved into peaks and canyons. The highest of these peaks is Blackhawk, with an elevation of 12,677 feet. The lowest point in the district covered by the map is about 8,600 feet, near the mouth of Spruce Gulch.

While the topography is thoroughly mountainous it is by no means of so rugged a character as that of the San Juan Mountains. The comparative smoothness of the wooded slopes about Rico is largely due to the remarkable extent to which landslides and accumulations of surface wash have buried and cloaked the lower slopes of the mountains. Inspection of the geological map (Pl. XLI) shows how almost the entire eastern slope of Expectation Mountain, the western slopes of C. H. C. and Newman hills, and many smaller areas are covered by surficial material.

GENERAL GEOLOGY.

The geological structure and history of the Rico Mountains have been admirably treated by Cross and Spencer in the report already cited. The reader is referred to that work, and particularly to the terse outline by Mr. Cross which forms the first chapter, for an account of the general geological features, knowledge of which is presupposed in the discussion of the ore deposits. But in order that the present report may not be wholly unintelligible in the absence of its companion paper, the following outline sketch has been prepared from the latter.

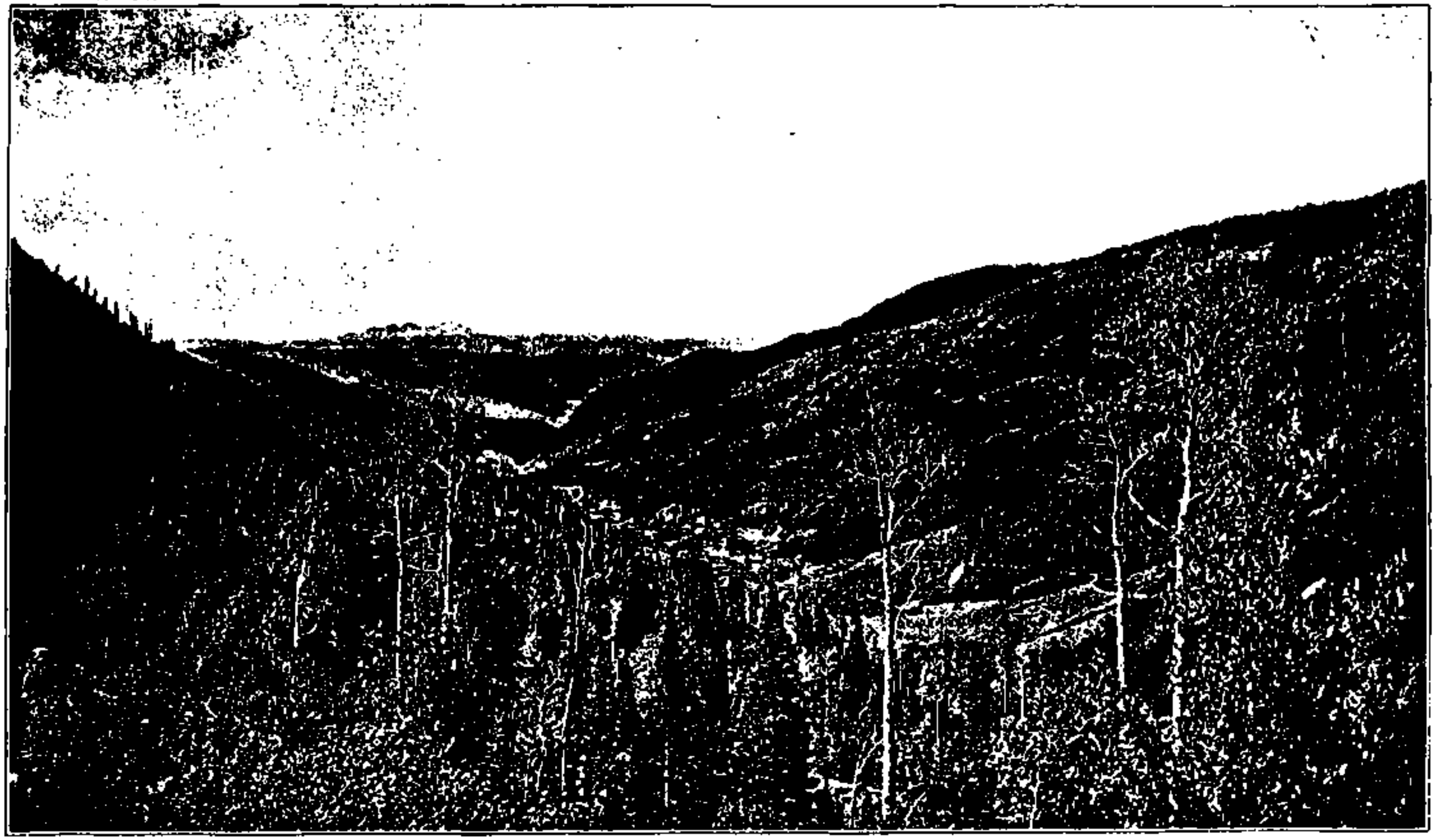
The accompanying geological map (Pl. XLI) includes but the central portion of the Rico "special area," of which a complete geological map may be found in Cross and Spencer's paper.[1]

The Rico Mountains are structurally determined by a local, dome-like uplift of originally nearly horizontal strata.[2] This uplift was due in minor part to the intrusion of masses of molten igneous rock, chiefly monzonite and monzonite-porphyry, in the form of sills, stocks, and dikes. But the greater portion of the elevation was effected by later upthrust and faulting. From north to south the dome is about 12 miles in diameter, and from east to west about 15 miles. The original vertical extent of the uplift is estimated at about 4,500 feet. This structural dome is now traversed from north to south by the Dolores River, and has been deeply eroded, particularly in its central portion, resulting in the present topography.

The rocks involved in this uplift range from Algonkian to Juratrias, the older being exposed in the central part of the area and the younger on its periphery. The Algonkian rocks consist of quartzites and schists, exposed just north of Rico and in the canyon of Silver Creek. They appear as fault blocks, in the heart of the dome, thrust

[1] Loc. cit., Pl. XXII.

[2] Ibid, Pl. VIII.



LOOKING SOUTH FROM C. H. C. HILL DOWN THE VALLEY OF THE DOLORES RIVER

The town of Rico, in the middleground, lies in the center of the [illegible] Rico Mountains. [illegible] La Plata Mountains [illegible] up from below into the later beds. Rocks of Devonian age are represented by massive limestone (the Ouray limestone) and an underlying quartzite. The former is exposed at the north end of the town of Rico and is much metamorphosed. The quartzite is seen in but few outcrops, and its base is nowhere revealed.

Above the Ouray limestone lies a thick series of sandstones, shales, and limestones, which pass up without any apparent unconformity into the Juratrias. This series is not readily separable into natural divisions on lithological grounds alone, but by the aid of certain fossiliferous beds Cross and Spencer have succeeded in dividing it into formations referable to different geological periods.

The beds immediately above the Devonian are Upper Carboniferous, and have been named the Hermosa formation. This formation has been further subdivided into a lower member of shales, sandstones, and subordinate limestones, a middle member, prevailingly limestones, and an upper member of shales and limestones. The middle member of the Hermosa is conspicuously represented in the cliffs of gray limestone which rise behind Newman Hill. The lower and middle members are mapped as a unit and indicated by a single color. The entire thickness of the Hermosa is about 1,800 feet.

Above the Hermosa lies the Rico formation, belonging to the Permo-Carboniferous, and consisting of coarse arkose sandstones, shales, and sandy, impure limestones. The prevailing color of these beds is dark maroon or chocolate, while the dominant tint of the Hermosa is gray. The base of the Rico lies a few feet above a sandy and very fossiliferous limestone containing *Fusulina cylindrica*, which is almost at the top of the Hermosa. The formation has a total thickness of about 300 feet.

Succeeding the Rico is the Dolores formation, included in the Juratrias, but probably corresponding to the Trias. It consists of sandstones, conglomerates, and sandy shales and limestones, prevailingly brick-red in color, and aggregating 1,600 feet in thickness. These are in part the familiar "Red Beds" of the Rocky Mountain region.

Overlying the Dolores is the La Plata formation, presumably Jurassic, consisting of two thick beds of light-colored sandstone separated by a thin bed of limestone. Its aggregate thickness in this region varies from 250 to 500 feet.

The La Plata is in turn succeeded by the McElmo beds, composed of variegated reddish and greenish shales and sandstones. The McElmo formation is regarded as Jurassic and is the youngest stratigraphic unit involved in the structure of the Rico dome, which is now preserved within the area described.

The last two formations occur only near the edges of the Rico area and contain no important ore deposits. All of the beds above the Devonian conform generally to the domical structure, dipping away on all sides from the geographical center of the uplift, which corresponds approximately to the town of Rico.

The foregoing sedimentary formations were intruded at an early stage of the uplift by numerous igneous masses in the forms of stocks, sills, and dikes. The intrusive magma solidified as monzonite or monzonite-porphyry. The occurrence of the stocks is well illustrated by the eruptive masses of Darling Ridge and Calico Peak. The sheets, or sills, and dikes are most abundant in the rocks of the Dolores formation, particularly near the head of Horse Creek.

After the igneous rocks had solidified the dome was further deformed by extensive faulting, the displacement in some cases exceeding 1,000 feet. The more important faults are indicated upon the geological map and are fully described in Cross and Spencer's report.

The later geological history of the region has been one of erosion and landsliding on an extensive scale, both of which closely connected processes have had an important influence upon mining developments. Although the landslides have obscured the relations of the ore bodies, erosion, on the other hand, by carving out the present mountains and canyons, has revealed the existence of the ores and rendered possible their exploitation.

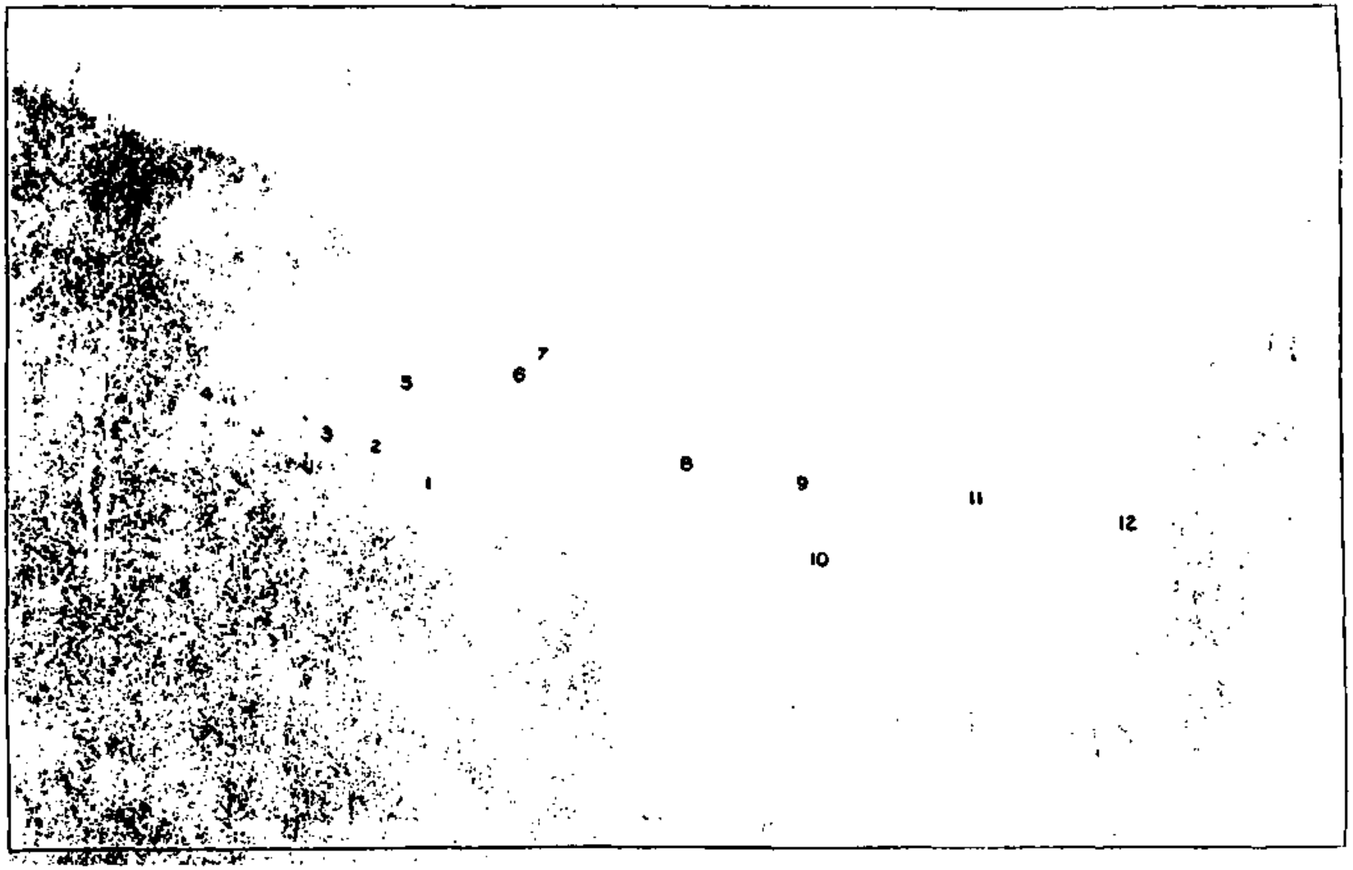
PRELIMINARY OUTLINE OF THE ORE DEPOSITS.

The ores of the Rico district show unusual variety in their occurrence as regards both form and genesis. To classify them strictly and consistently, in accordance with either shape or origin, would be difficult and for ordinary purposes confusing. The units of such classification would, in many cases, be not ore bodies, but parts of ore bodies. It is proposed in this report to treat the deposits under four general heads, namely: (1) lodes, (2) blankets (*Lagergänge*, or bed veins, of von Cotta, in part), (3) replacements in limestone, and (4) stocks. This is confessedly and obviously a rough grouping for convenience and clearness of treatment, and is not intended as a scientific classification.

Under the first head will be described simple or complex fissure veins, usually nearly vertical, which when they occur in sedimentary formations cut across the planes of bedding. They are fractures or fissures in the rocks, which have been afterwards filled with ore or valueless vein matter.

Under the second head will be treated various deposits usually more nearly horizontal than vertical, and lying parallel to the planes of bedding or to the surfaces of intruded sheets of igneous rock. These are the deposits locally known as "contacts." This term, used in a sense that has no necessary connection with its true geological meaning, has unfortunately found its way into literature,[1] and has been so

[1] Farish, loc. cit., uses the word "contact" in quotation marks, but Rickard, loc. cit., provides no such safeguard against confusion.



1. Enterprise mine, group tunnel.
2. Silver Age tunnel.
3. Wakeman and Golden Age tunnel.
4. Isabella shaft.
5. Enterprise shaft.
6. Jumbo shaft.
7. [illegible] shaft.
8. [illegible]
9. Stephens tunnel.
10. Lexington tunnel.
11. Rico-Aspen mine, Syndicate tunnel.
12. [illegible] tunnel.

NEWMAN HILL, FROM THE NORTHWEST

universally adopted by the miners that it is difficult to altogether avoid its use. Wherever employed, however, the word will be placed in quotation marks, indicating its true standing as miners' vernacular.

Under the third head will be considered those deposits, often irregular in form, which have resulted from the metasomatic replacement of limestone by ore.

Lastly, under the fourth head, will be noticed a few small ore bodies often referred to as "chimneys," of which the Johnny Bull is the principal example in this region.

It will be shown later on that no sharp distinction exists between these various deposits. Lodes of flat dip may pass into bedding faults along weak strata, producing breccias which, when mineralized, are classed as blankets. The mineralization of such a breccia, particularly if the material be calcareous shale, is likely to be largely by metasomatic replacement, producing a deposit closely akin to those resulting from the simple replacement of limestone. Moreover, the ore bodies grouped under the second and third heads are always intimately connected with fissures or lodes which may or may not be themselves productive.

The greater part of the product of the district has come from the blankets. Some of the lodes have proved rich, but their value has invariably fallen below the limit of profitable working at a remarkably shallow depth, which generally bears a constant relation to some overlying blanket with which the lode or lodes connect. Some important bodies of ore have also been formed by direct replacement of limestone.

The bulk of the ore has been found in the Carboniferous sedimentary series, particularly that portion of it known as the Hermosa formation. This is nearly equivalent to saying that most of the ore has come from the central portion of the district, in the heart of the domical uplift of the Rico Mountains.

The ores consist primarily of galena, often highly argentiferous and associated with rich silver-bearing minerals. In many deposits more or less complete oxidation of the primary ores has taken place, resulting in pulverulent earthy ores, often very rich in silver.

DISTRIBUTION OF THE ORES.

In all probability more than half of the ore produced in the Rico district has come from Newman Hill. This name is applied to the slopes immediately south and east of Rico, constituting the western flank of Dolores Mountain. Newman Hill may be considered as bounded on the north by Silver Creek, on the west by the Dolores River, on the south by Deadwood Gulch, and on the east by the cliffs formed by the massive bed of limestone characteristic of the medial division of the Hermosa. On this slope, which is deeply covered with surface wash, are the Enterprise, Rico-Aspen, Newman, Union-Carbonate, and other mines, in which the ore occurred partly in lodes and partly in blankets. Of the latter the principal one is locally known as the Newman Hill, or Enterprise, "contact."

Also on the east side of the Dolores River, but north of Silver Creek, is Nigger Baby Hill, a spur of Telescope Mountain. This hill has been productive since 1879. The ore occurs in oxidized form in lodes, which in their upper portions possess so flat a dip as to constitute essentially blanket deposits.

C. H. C. Hill lies immediately north of Nigger Baby Hill. It is a landslide area, honeycombed with workings, from which much ore has been taken. The ore, largely oxidized, occurs in blankets, the continuity of which has been greatly broken by landslide movements.

From the three hills mentioned has come the greater part of the Rico ore. There are, however, several important outlying deposits. The most prominent of these is in the Blackhawk mine, between Silver Creek and Allyn Gulch, where the ore occurs oxidized in a lode and as sulphide replacement deposits in massive limestone. Another example is the Puzzle mine, on Horse Creek, about three-quarters of a mile from its mouth, where the ore also occurred replacing limestone. The Johnny Bull mine, on Johnny Bull Mountain, near the head of Horse Creek, has also produced some ore.

The entire basin of Horse Creek and the eastern slope of Expectation Mountain are dotted with prospects, many of which have produced small quantities of ore, but nearly all are now abandoned.

By reference to the geological map (Pl. XLI) the preponderance of the important ore bodies occurring in the Hermosa, particularly the Lower and Middle Hermosa, will be evident. Near the periphery of the dome, where the Juratrias sediments now constitute the surface, no large ore bodies have been found. The Johnny Bull, it is true, occurs in these rocks, but the ore body, although at one time giving rise to considerable excitement, proved to be little more than a pocket.

MINERALOGY OF THE ORES.

The ores of the Rico district present few noteworthy or peculiar mineralogical features, and need receive but brief treatment under this head. The bulk of them may be roughly divided into (1) pyritic ores, usually of very low grade, and (2) argentiferous galena ores, sometimes containing rich silver minerals. The former constitute the characteristic vein filling of most of the lodes, and also occur in many of the blankets and other deposits. The latter form the workable ore bodies, deposited under various specially favorable circumstances of concentration. The two kinds of ore are not capable of sharp mineralogical or commercial distinction, and are not necessarily of different age.

The minerals occurring as a direct result of the general processes of mineralization may be classed as ore minerals and gangue minerals. Among the former are included all of the so-called "metallic minerals," whether or no they actually constitute ore in the commercial sense. Under the latter are embraced those nonmetallic minerals, such as quartz, which commonly serve as matrix for the valuable ore constituents.

ORE MINERALS.

Pyrite is by far the most abundant ore mineral in the district. Associated with quartz and small amounts of chalcopyrite, sphalerite, and galena, it constitutes the practically worthless filling of most of the lodes. It is found in large blanket-like masses, free from gangue, in C. H. C. Hill. In similar masses, but usually in more solid condition, it is abundant as a replacement of limestone. This is the mode of its occurrence in the Blackhawk mine, where it is frequently associated with *fluorite*, and grades by increase of chalcopyrite and galena into workable ore. Although commonly containing small quantities of silver and gold, the pyrite has hitherto proved too low in grade for successful treatment. Rickard[1] records that the pyrite from the northwesterly lodes in the Enterprise mine usually afforded on assay from 4 to 8 ounces of silver and traces of gold. In the Gold Anchor prospect in Bull Basin, a large body of pyrite was found which is said to have indicated, in single assays, as much as 90 ounces of gold per ton, but which as a whole did not pay the cost of extraction.

Galena, a very important ore mineral, occurs abundantly in the Enterprise blanket and in most of the bodies of unoxidized ore that have been worked in the district. It is always argentiferous, but apparently does not constitute rich ore unless accompanied by argentite, tetrahedrite (freibergite?), proustite, or polybasite, as is the case in the Newman Hill mines. On the other hand, it nowhere occurs in sufficiently large masses to be workable for its lead alone. It presents no unusual peculiarities in this region, and is, as elsewhere, nearly always accompanied by sphalerite.

Sphalerite, or zinc blende, is an abundant constituent of the rich ores of Newman Hill, which sometimes contain over 15 per cent of zinc. Its common associates in these ores are galena, chalcopyrite, rhodochrosite, and quartz, and it occurs both in the northeasterly lodes and in the blanket. It is also found in massive granular form, associated with a little chalcopyrite, galena, and fluorite, in the Blackhawk mine, where it makes up a considerable part of the large replacement bodies in limestone. In the Atlantic Cable claim it occurs in coarsely crystalline nodular masses, associated with chlorite,

[1] Loc. cit., p. 940.

specularite, chalcopyrite, and galena, in limestone. This sphalerite is dark brown, while that in the Newman Hill veins is usually rosin colored. It is also abundant in the Sambo mine, and in the Bancroft and Lily D. prospects, associated with galena. The occurrence of sphalerite has hitherto been purely an objectionable feature in the ores, owing to the penalty attached by the smelters to ores containing over 10 per cent of zinc. But in 1900 experiments were being made to determine the feasibility of working some of the sphaleritic ores for zinc alone, and in 1901 zinc ore was being extracted in commercial quantities from the Atlantic Cable and Bancroft claims.

Chalcopyrite, or copper pyrite, is not very abundant in the Rico district, although nearly always present with galena and sphalerite in the workable ores. Associated with pyrite, fluorite, and some finely granular galena and sphalerite, it formed some of the best ore in the Blackhawk replacement bodies, where it often occurred in fine concentric or irregularly curved, narrow bands. It is present in small quantity in the blanket and lode ores of Newman Hill, in the Silver Swan, Aztec, and Atlantic Cable prospects, and in many other lodes and blankets throughout the district.

Tetrahedrite, or gray copper ore, occurs in the rich blanket ores of the Enterprise and Rico-Aspen mines and in some of the northeasterly lodes. It is a valuable constituent on account of its argentiferous character. It is here associated with sphalerite, polybasite, galena, rhodochrosite, and quartz. It also occurs in these mines in ore replacing gypsum, the gangue in such cases being partly the transparent crystalline form of gypsum known as selenite. Small amounts of tetrahedrite are found replacing sandstone in the Gold Anchor prospect in Bull Basin. It is probably present also in the Aztec lode, with chalcopyrite, and may have formed part of the Johnny Bull ore. A small pocket of tetrahedrite was extracted from the Iron lode, but the mineral apparently does not occur in the replacement deposits of this mine. A little occurs also, with quartz, in the Eureka, a prospect near the head of Iron Draw. It is nowhere abundant, and is generally indicative of high-grade ore, although the latter is not necessarily present in large amount.

Specularite, the crystalline variety of hematite, occurs abundantly in several mines and prospects in the metamorphosed Devonian beds near Rico. Among these may be named the Iron Dollar, Eighty-Eight, Atlantic Cable, Shamrock, and Smuggler. It is closely associated with chlorite, epidote, garnet, and wollastonite (and perhaps vesuvianite), as well as galena, sphalerite, and chalcopyrite, and its formation was evidently connected with the metamorphism of the Devonian limestone. It is of no value as an ore in this region, but has been sometimes mistaken for sphalerite.

Magnetite has been mined in small amounts for fluxing purposes from the Magnet prospect on the north side of Darling Ridge, and from the Eagle prospect near the head of Sulphur Creek. It occurs massive, with a little chalcopyrite, replacing limestone. It may contain half an ounce of silver and $2 in gold per ton. Some magnetite occurs in the Atlantic Cable claim, with specularite.

Argentite, proustite, polybasite, and perhaps *stephanite*, occur in the rich blanket and lode ores of Newman Hill. They were evidently among the last ore minerals to form, and to them was mainly due the richness of these deposits. They are almost invariably found in vugs in the more solid ore, and when present in the lodes occur along the medial plane of the vein in the spaces left by the comb structure of the quartz and other minerals. Argentite is found in black, rounded masses, suggestive of particles of shoemaker's wax, which have softened and fitted themselves to the interstices between the earlier crystals. Polybasite and proustite also occur in vugs, but in implanted crystals of the forms characterizing these minerals. Stephanite was not identified at the time of visit, but its occurrence has been reported by Farish,[1] who also mentions pyrargyrite. These rich silver-bearing minerals were not seen elsewhere in the district in 1900; but argentite is said to have occurred in the Puzzle mine, in a quartzose gangue, replacing limestone.

Native silver is reported from the Enterprise and Puzzle mines, but none was seen in 1900. It was probably a product of oxidation.

Free gold is rarely detected in the Rico ore deposits. Some is said to have been found associated with sphalerite and chalcopyrite in the Enterprise mine, and some embedded in rhodochrosite in the Eureka vein of the same mine. A little free gold has also been found in prospects near Calico Peak, but none was seen in place. The ore of the Johnny Bull mine contained considerable gold, with tellurium and traces of bismuth, but it is not known whether any of the gold occurred native. Gold, associated with a little molybdenum, occurred in the Uncle Remus mine, but whether free or not can not now be ascertained.

Native copper was noted only in the California prospect near the head of Iron Draw, as small crystalline sheets or skins in the country rock.

GANGUE MINERALS.

Quartz is by far the most abundant gangue mineral in the region. It is nearly always associated with pyrite and constitutes the common filling of the lode fissures. Although usually present in the workable ores, it is there associated with other gangue minerals. The lode quartz shows no special features peculiar to this region and demands no detailed description. In the form of jasperoid[2] (a cryptocrystalline

[1] Loc. cit., p. 161.

[2] See J. E. Spurr, Mon. U. S. Geol. Survey Vol. XXXI, 1898, p. 219.

aggregate commonly associated with replacement deposits) quartz occurs in the Blackhawk mine, in the Atlantic Cable claim, and in the blanket of the Sambo mine. In the Blackhawk mine, also, are found spongy, cavernous masses of rusty quartz, apparently due to the removal of limestone, by solution, from a network of quartz stringers (Pl. XXVIII, A). Quartz is abundant in some of the blanket breccias as a replacement of the brecciated material. In the case of the nearly black Hermosa shales, many of the fragments are still recognizable as dark patches in the white quartz, although the microscope shows that they have been altered to cryptocrystalline quartzose aggregates. In the main blanket of the Union-Carbonate mine, fragments of monzonite-porphyry have been more or less completely transformed into very spongy masses of white quartz, sometimes containing pyrite. A somewhat similar silicification of porphyry has taken place alongside the lode fissures of the Mohawk and Marriage Stake prospects, in Horse Gulch. In these cases, however, the resulting siliceous skeleton still preserves in a measure the original porphyritic appearance of the rock.

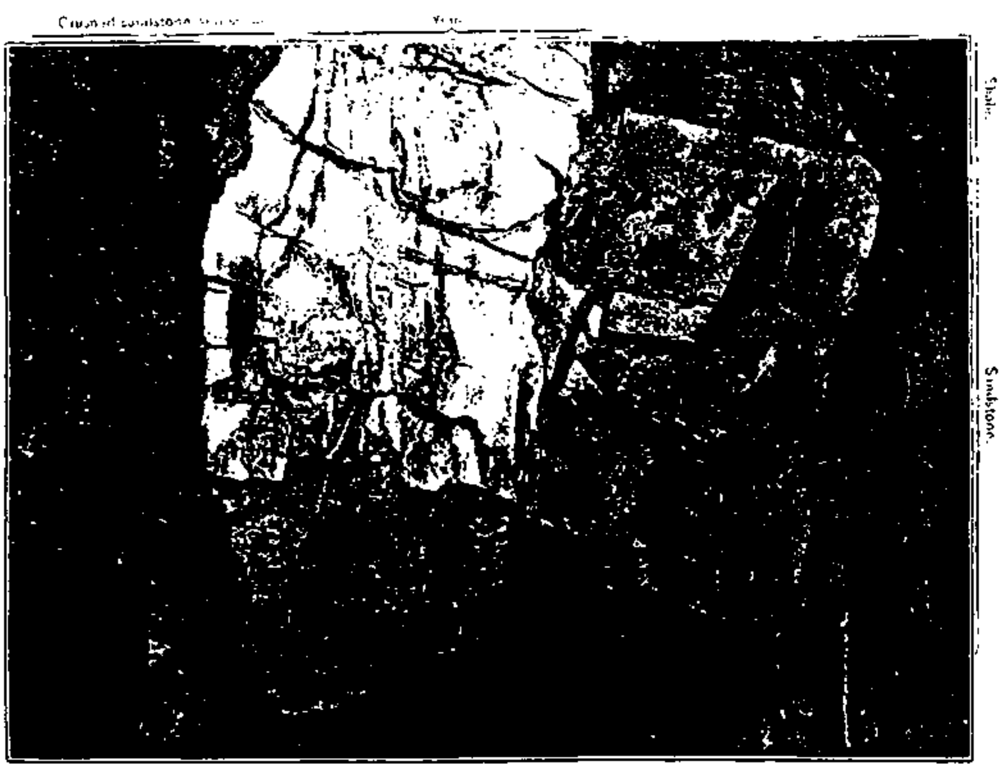
Rhodochrosite, the carbonate of manganese, is present in the rich upper portions of the northeasterly lodes of Newman Hill and in the Enterprise blanket. Its delicate pink color makes it easily recognizable, and it is important in these mines as a rough indication of good ore. It occurs massive, often irregularly but beautifully banded with the quartz and ore of the lodes. It does not, as far as known, occur in this region in the large well-formed rhombohedral crystals which characterize it in some other localities. A little residual rhodochrosite was noted in the oxidized Little Maggie vein, at the Blackhawk mine, but it is not generally abundant outside of Newman Hill. Some of the "spar" veins in other portions of the region have a slight pinkish tint, however, and decompose in part to black oxide of manganese, showing either that some of this mineral is present, or that the "spar" is manganiferous.

Calcite, or the common "spar" of the miners, is abundant in the veins of Nigger Baby Hill, where it takes the usual place of quartz as the principal gangue mineral. It is generally finely crystalline, more or less impure, and often resembles ordinary limestone. It is always manganiferous, and readily undergoes decomposition, whereby the calcium carbonate is largely removed and a soft black mass of oxidized manganiferous ore left behind. Calcite is naturally often present as gangue in the replacements of limestone by ore.

Fluorite, or fluorspar, is not of widespread occurrence in the Rico ore deposits, but is abundant in the displacement ore bodies of the Blackhawk mine and in the Fortune and Duncan prospect north of Silver Creek. In the Blackhawk it forms the gangue of pyrite, chalcopyrite, sphalerite, and galena in the large pay shoot outcropping at the surface near the bunk house. It is pale lilac, pink, or color-

A. CAVERNOUS RUSTY QUARTZ AS SEEN ON THE M LEVEL OF THE [illegible] MINE

[illegible]



B. JUMBO NO. 3 VEIN, NEAR THE NORTH BREAST OF THE 150-FOOT LEVEL, ENTERPRISE MINE.

Photograph by G. W. Tower.

less, and easily recognized by its hardness and cleavage. In the Fortune and Duncan it constitutes the gangue of a low-grade pyritic ore occupying a breccia zone between quartzite and limestone. It is nearly colorless, with slight pinkish and greenish tints, and forms with pyrite and chalcopyrite a friable crystalline aggregate. A small quantity of fluorite also occurs in the Hibernia tunnel.

Gypsum occurs as a gangue mineral, so far as observed, only in those ores which have replaced massive gypsum in Newman Hill. A portion of the gypsum has in such cases recrystallized as transparent plates of selenite.

Barite is not known in this region as the gangue of any workable ore body. It occurs, however, on a claim adjoining the Aztec mine, in a vein supposed to be the same as that worked in the latter mine.

Chlorite occurs abundantly as a gangue for sphalerite, chalcopyrite and specularite, in the Atlantic Cable and other prospects in the Devonian limestone. It is cryptocrystalline and massive.

Kaolinite and *sericite* are not abundant in this region, and can scarcely be considered as gangue minerals. Some of the former mineral, however, occurs associated with the ore in the Johnny Bull mine, while sericite is found in connection with the C. H. C. Hill blanket.

PARAGENESIS.

By *paragenesis* is here meant the association of the various ore and gangue minerals, with special reference to the mode and order of their formation.

Although these minerals, as indicated in the preceding section, are commonly found in more or less characteristic association, no constant and regular order of deposition has been discovered. Careful study of the banded veins of Newman Hill has failed to show that this banding can be explained by any simple depositional sequence of the component minerals. Each mineral has evidently been developed at many different times during the whole period of mineralization. The only generalizations which it appears safe to make are that, in Newman Hill the rich silver ores, proustite, argentite, and polybasite, were the last ore minerals to form in the northeasterly lodes and in the Enterprise blanket, and that there was deposition of practically barren quartz and a little pyrite, which was also subsequent to the formation of the galena, sphalerite, and rhodochrosite. Whether this barren veining preceded, followed, or coincided with the deposition of the rich silver minerals, is not known. It is supposed to have followed it.

PRODUCTS OF OXIDATION OR WEATHERING.

The access of surface waters to the upper portions of many of the lodes and to some of the blankets and replacement ore bodies has resulted in a variety of products, many of them earthy and of obscure mineralogical character. The rather thorough oxidation of the shattered pyritic blankets of C. H. C. Hill has given rise to great masses of limonitic iron ore, sometimes containing gold and silver, but usually of no value. Associated with this are earthy lead sulphate, pulverulent hydrous silica, jarosite (hydrous sulphate of iron and potash), sericite, halloysite, gypsum (derived from limestone by sulphate solutions from oxidizing pyrite), silver in unknown combination, and probably many other minerals. In Nigger Baby Hill the decay of the calcitic veins to a depth of some 200 feet has resulted in soft, black, earthy ores consisting largely of hydrous oxides of manganese and iron, obscure hydrous compounds of alumina, carbonates of copper in small amounts, and silver, lead, and zinc in unknown conditions, probably in part as carbonates. Similar products have resulted from the alteration of a bed of impure limestone in the Forest-Payroll mine. In the Puzzle mine the argentite is stated by Purington[1] to have been partly altered to native silver and to embolite, the chlorbromide of silver; and on the M. A. C. claim, adjoining the Puzzle, in a shaft now inaccessible, was found a soft mass of pale-blue allophane (hydrous silicate of alumina) and kaolinite in a cavity dissolved in the limestone.

Although not strictly a product of oxidation and weathering, it may be well to mention in this place the pulverulent gray mixture of dolomite and celestite which has remained as a residue after the solution of the gypsum of Newman Hill.

OCCURRENCE OF THE ORES.

DEFINITIONS.

While it is undesirable in a report of this character to enter at length into the complex subject of the classification and nomenclature of ore bodies, it is essential to clearness of presentation that the meanings of such terms as are used in the description of the Rico ore deposits should be clearly understood. The following definitions are intended to make plain the terminology adopted in this paper, and need have no currency outside of its pages.

Fissure vein is used as von Cotta defined it—the filling of a fissure. *Lode* is applied as a more comprehensive term, and may mean either a simple fissure vein or a complex assemblage of closely spaced veins or stringers, sometimes including a certain proportion of mineralized country rock occurring alongside of and within the fissure zone. A lode is roughly tabular in form and when occurring in sedimentary rocks cuts across the beds at an appreciable angle. It is usually more nearly vertical than horizontal. That portion of a vein or lode which consists of workable ore is termed a *pay shoot*.

The word *blanket* is used to designate a zone or lens, composed of

[1] Unpublished MS.

mechanically or chemically disintegrated material, lying parallel to the bedding of the sedimentary series within which it is inclosed. Such a mass is always referred to as a "contact" by the miners of Rico. In contradistinction to a lode a blanket is usually more nearly horizontal than vertical. The material of a blanket is normally soft as compared with the rocks which immediately overlie or underlie it. In most cases its unconsolidated character is due to the brecciation or chemical alteration of a bed which either was originally intrinsically weak or has been placed in such circumstances as to become disintegrated. Various blankets will be described, due to different combinations of causes, from simple brecciation of a weak stratum by a bedding fault to chemical decomposition without mechanical aid. Blankets are sometimes overlain or underlain by sheets of igneous rock which have been intruded earlier into the sedimentary series, and which, so far as the blankets are concerned, behave as massive irregular beds.

Blankets are frequently mineralized and contain bodies of ore which may or may not be coextensive with the blanket itself. Such ore bodies will be termed *pay shoots*, as in the case of lodes.

Replacement ore bodies in limestone require no special definition. They embrace those ore masses, often of irregular form, which have molecularly replaced the limestone through the process known as metasomatism.

Stocks are those ore bodies commonly referred to as "chimneys." They are more or less solid masses of ore, roughly circular in plan, with their longest dimension nearly vertical. Their formation, while usually initiated by two or more intersecting fissures, is accompanied by considerable metasomatic replacement of the country rock.

LODES.

FISSURE SYSTEMS.

Partly on account of the oxidation of their upper portions, but more largely through the concealment of their outcrops by landslides and wash, the lodes of the Rico district are very poorly exposed on the surface. Furthermore, as will be shown later, several of the lodes never did extend to the surface. These conditions make a comprehensive study of the fissures, with reference to the area as a whole, very difficult. Certain groups of fissures, such as those in Newman or Nigger Baby hills, may, through the aid of underground workings, be studied in some detail, but the identification or comparison of the fissures of any such local group with those of another group is rarely satisfactory. Such comparisons usually bring out marked differences, but the transitions connecting these differences are nearly always concealed from view.

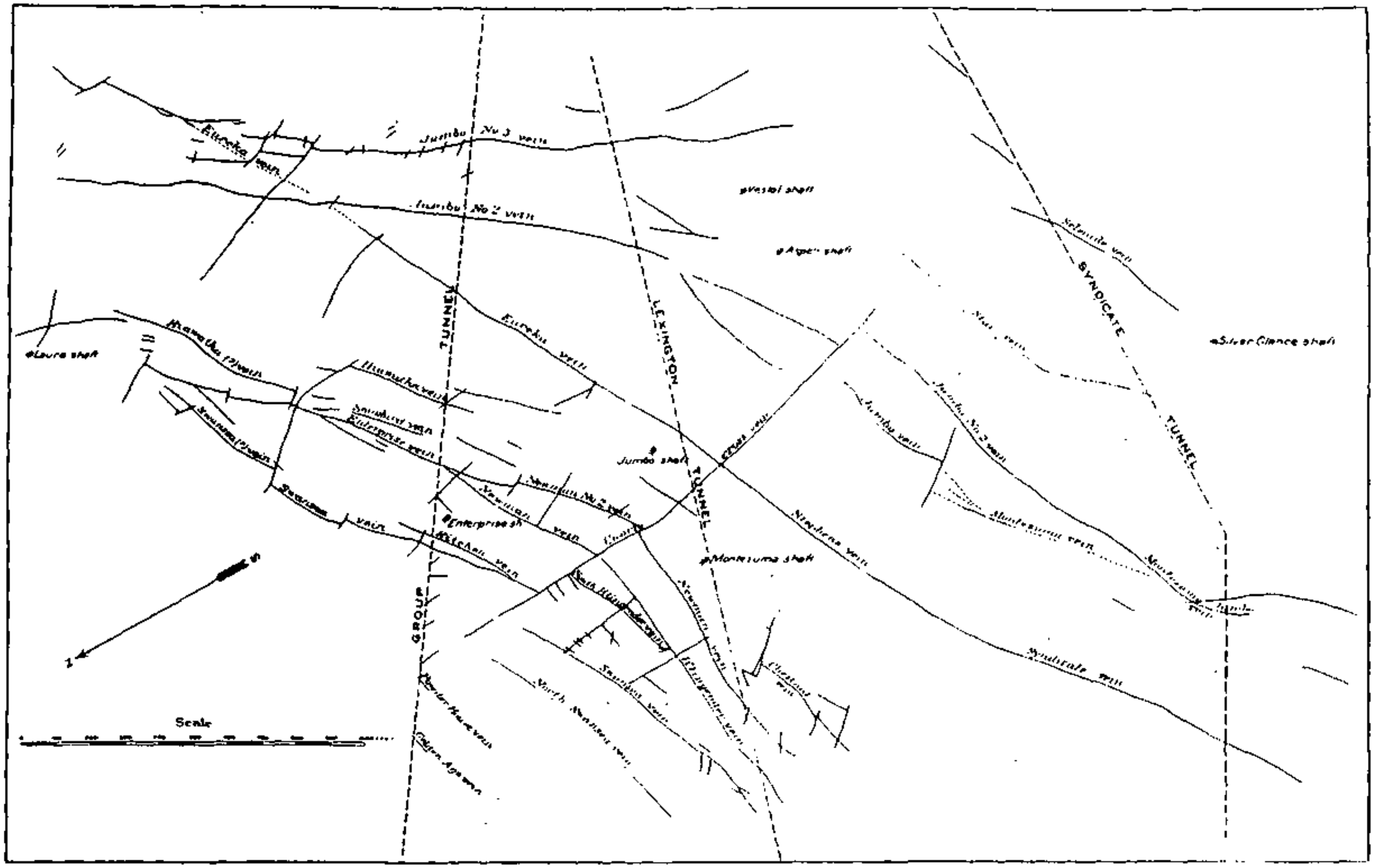
The distribution of the lode fissures is closely connected with the general geological structure of the district. They are most abundant in the central portion of the area and decrease in number and importance toward the periphery of the dome-like uplift of strata from which the Rico Mountains have been carved. The most important fissures are undoubtedly those of Newman Hill. Second in number and productiveness are those of Nigger Baby Hill. Other notable fissures are connected with the great dislocation known as the Blackhawk fault. Some of these seem to have played an important part in the mineralization of C. H. C. Hill, but so disturbed and buried are they by landslide material that any thorough study of them is impossible. Many other lode fissures occur in Horse Gulch and on Expectation Mountain, but they are poorly exposed and none of them have proved of great importance as ore-bearing lodes.

The principal fissures of Newman Hill fall into two classes, distinguished by their strikes or trends, and by the character of the veins which fill them. The fissures of the more important class are characterized by strikes varying from about N. 25° E. to N. 65° E. They are locally known as "verticals" or "pay veins," but will be referred to in this report as *northeasterly* fissures. These are occupied by the ore-bearing lodes of Newman Hill, such as the Swansea, Kitchen, Enterprise, Songbird, Hiawatha, Eureka, Jumbo No. 2, Jumbo No. 3, Chestnut, Klingender, Montezuma, Selenide, Star, and other veins.

The second class of lode fissures encountered in Newman Hill is characterized by strikes ranging from nearly north and south to about N. 45° W. The fissures correspond to the "barren veins" or "cross veins" of the Newman Hill miners, but will be referred to in this paper simply as *northwesterly* fissures. They are not themselves ore bearing, although, as will be shown later, they exercised an important influence upon the deposition of ore in an overlying blanket. Some idea of the disposition of the two sets of fissures may be gained from Pl. XXIX, compiled from underground workings.

The northeasterly fissures are usually clean, simple fractures, nearly vertical, or dipping southeastward at high angles. They range in width from a mere crack up to 2 or 3 feet; but a width of 18 inches is rare, and the average is probably not much over 6 inches. They traverse sandstones, shales, and limestones belonging to the lower division of the Hermosa formation. These beds dip somewhat east of south at a general angle of from 10 to 15 degrees. The fissures were originally opened by normal faulting, of which the known throw has in no case exceeded 10 feet, and is usually much less.

The fissures are limited above by the main Newman Hill blanket, commonly known as the "contact." At a varying distance below it, usually less than 20 feet, the fissures begin to split up into smaller fractures (fig. 43). This division into countless small irregular fissures



MAP SHOWING SOME OF THE MORE IMPORTANT LODE FISSURES IN THE ENTERPRISE NEWMAN AND RICO-ASPEN MINES is particularly noticeable within a series of shales and very thin-bedded sandstones which underlie the blanket. Some fissures are known above the blanket, but they contain no ore and can not be identified with those below it.

The conditions which limit the northeasterly fissures in length are not well known, as apparently none of the lodes have been worked to the point of disappearance. Toward the southwest some of the more continuous ones probably reach and are cut off by the Deadwood fault. Toward the northeast the fissures very likely die out before Silver Creek is reached. Several transverse faults are known to intervene between the workings of the Enterprise mine and Silver Creek, but in spite of these the productive northeasterly fissures should have been recognized in the Onamo, Pro Patria, Fickle Goddess, or Hibernia tunnels, did they preserve their strength and regular character northward. Several northeasterly fissures are cut in the Fickle Goddess and Pro Patria tunnels, but they show no resemblance to the productive lodes farther south. It is probable that the prominent northeasterly fissures known in the Enterprise, Newman, and Rico-Aspen mines do not persist across the thick intrusive sheet of monzonite-porphyry which rises up over the northern slope of Newman Hill (see Pl. XLI), and in which is sunk the Skeptical shaft. They either die out before reaching it or are deflected into other courses.

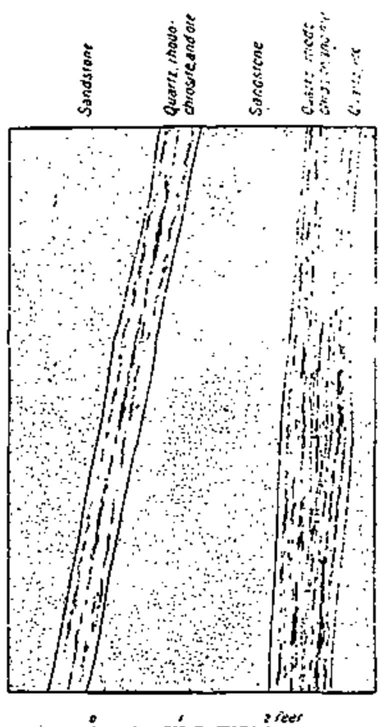


FIG. 40.—Cross section of Jumbo No. 3 lode, north breast, intermediate level, Enterprise mine.

The most persistent and regular of all the Newman Hill fissures is that worked for a distance of over 3,000 feet under the names of the Eureka, Stephens, and Syndicate veins. On the north this fissure joins the Jumbo No. 3 fissure, which, from the supposed junction point northward, has the direction of the Eureka lode and not of the Jumbo No. 3 proper (see Pl. XXIX). This Jumbo No. 3–Eureka fissure continues northeastward to the limits of the Enterprise ground, splitting near the breast into a sheeted zone (fig. 40) carrying rather low-grade ore.

None of the northeasterly fissures have been explored to great depth, but the section afforded by the Lexington tunnel, about 450 feet below the Newman Hill blanket, shows that the fissures are smaller at this depth than in the workings above.

The northwesterly fissures of Newman Hill are more abundant than the northeasterly. But owing to the fact that they contain no workable ore they are seldom drifted on and are consequently not so well exposed as the latter. Their dips range from vertical to about 40°, and may be northeastward or southward, the former being more common. The average dip is lower than that of the northeasterly fissures.

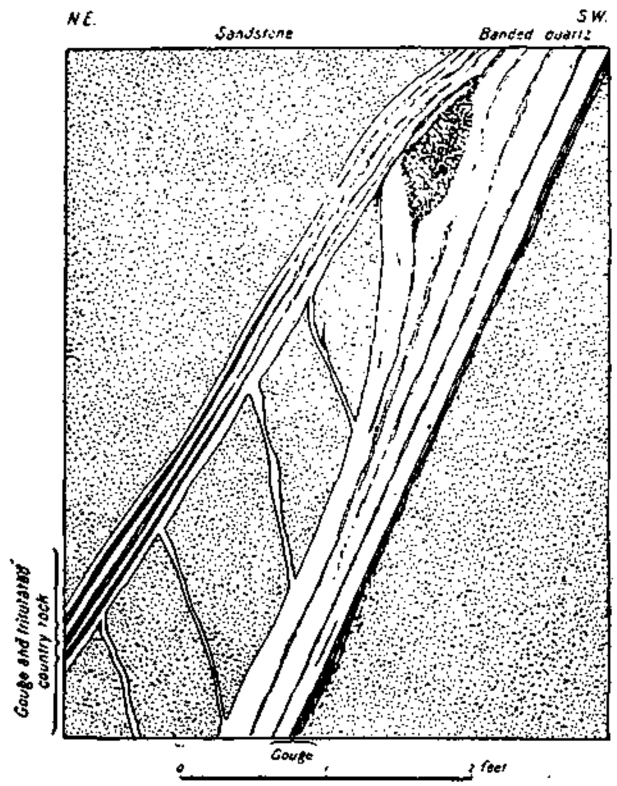


FIG. 41.—Cross section of the James cross vein, south breast of James drift, Newman mine.

They vary greatly in width, from a mere crevice up to 3 or 4 feet. Although often simple fractures, they very frequently show more complex form, as shown in fig. 41. These fissures appear to have been opened by normal faulting, and in some cases are reported to have faulted the overlying blanket to the extent of 25 feet throw. Vertical displacement to this amount is, however, rather exceptional. Moreover, as will be seen later, the structure of the northwesterly lodes shows that a considerable part of the observed faulting may have taken place since the fissures were first formed.

In the Union-Carbonate mine, on the northern spur of Dolores Mountain, the fissures show few resemblances to those of the more southerly portion of Newman Hill. The productive northeasterly fissures are not developed. Numerous other fissures are found striking from N. 60° W. to N. 75° W.—that is, more westerly than the northwesterly veins of the Enterprise mine. Fissures of this general trend are dominant on the northern slope of Dolores Mountain, as shown in the Union-Carbonate and Forest-Payroll workings.

Passing beyond Newman Hill, it is found that northeasterly fissures are of small importance in other portions of the district. Several have been worked at the eastern base of Expectation Mountain, between Sulphur Creek and Iron Draw, in the N. A. Cowdrey, Tomale, Argonaut, and Bancroft mines. The strikes of these fissures range from N. 40° E. to N. 60° E. They are fairly abundant, but small, rather irregular, and apparently not very persistent.

On Nigger Baby Hill the economically important fissures are northwesterly in trend. Such are the Hope, Cross, Grand View, Phœnix, and Butler veins. Near the top of the hill and on the western slope the average strike is N. 30° W. and the average dip northeasterly at about 25°, although the Cobbler vein is steeper. As these fissures are followed downward their dips are found to increase. The Phœnix vein, with dips sometimes as low as 15° in the upper workings, steepens to 45° in the lower tunnels, or the southern slope of the hill. The Cobbler vein is practically vertical on the Phœnix No. 1 level, and the Butler veins, outcropping still higher up the hill, dip northeasterly at about 70° on the Alma Mater level. The strike of the fissures is also found to be more westerly as they are followed southeast, toward Silver Creek. The Nellie Bly vein is rather exceptional in striking nearly east and west. If, as supposed by some, it is the same as the Grand View vein, it shows a change of course in the latter amounting to over 60°.

The Iron lode, on the southeastern slope of Nigger Baby Hill, strikes N. 16° W. and dips easterly at about 75°. Its trend is thus more northerly than the majority of the lode fissures on the hill.

The Hope, or Grand View, Cross, Phœnix, and Nellie Bly fissures are notable from the fact that their strikes are very nearly parallel to those of the beds which inclose them, while their dips, although generally slightly steeper in angle, correspond in direction to those of the strata. Consequently these fissures cross the bedding planes at a very acute angle, causing the lodes, particularly in the upper part of the hill, to closely resemble the form of deposit that has been termed a blanket.

The main fissure, upon which are located the Blackhawk, Argentine, and Uncle Ned mines, has a general course of N. 40° W. and dips northeast at angles varying from 50° to 80°. The geological work of Cross and Spencer has shown that this fissure probably constitutes a part of a pronounced zone of faulting which they have called the Blackhawk fault. The same fissure passes under the landslide of C. H. C. Hill, and probably corresponds to the Pigeon lode, or so-called "big fissure" of that hill, and with the C. V. G. lode at Burns. It is quite possible also that the A. B. G. lode, on the west side of the river, is on a branch of the same fault, for, as the geological map shows, it occupies a fault fissure. Details of the Blackhawk fissure are difficult to obtain. It is undoubtedly the largest and most persistent in the region, attaining in places a width of over 40 feet. It is not likely, however, that any open space of this width existed at any one time. The great width of the lode at certain places is due to the passage of a simple fracture into a sheeted zone, and also to repeated reopenings and fillings along the same zone of fracture.

Intimately connected with the Blackhawk fissure are several fissures striking about N. 70° W. and falling into the main fissure on its northeast side. Such are the Little Maggie and Alleghany veins, the former dipping northeast at about 60°, while the latter dips southwest at about 70°. Cross and Spencer have regarded these fissures as probably structural faults,[1] but they are small, simple fractures which have not effected any discoverable faulting of the beds which they traverse. Just northeast of them lies a fissure of similar trend, but of no economic importance. This, as shown by the geological map (Pl. XLI), is a distinct fault.

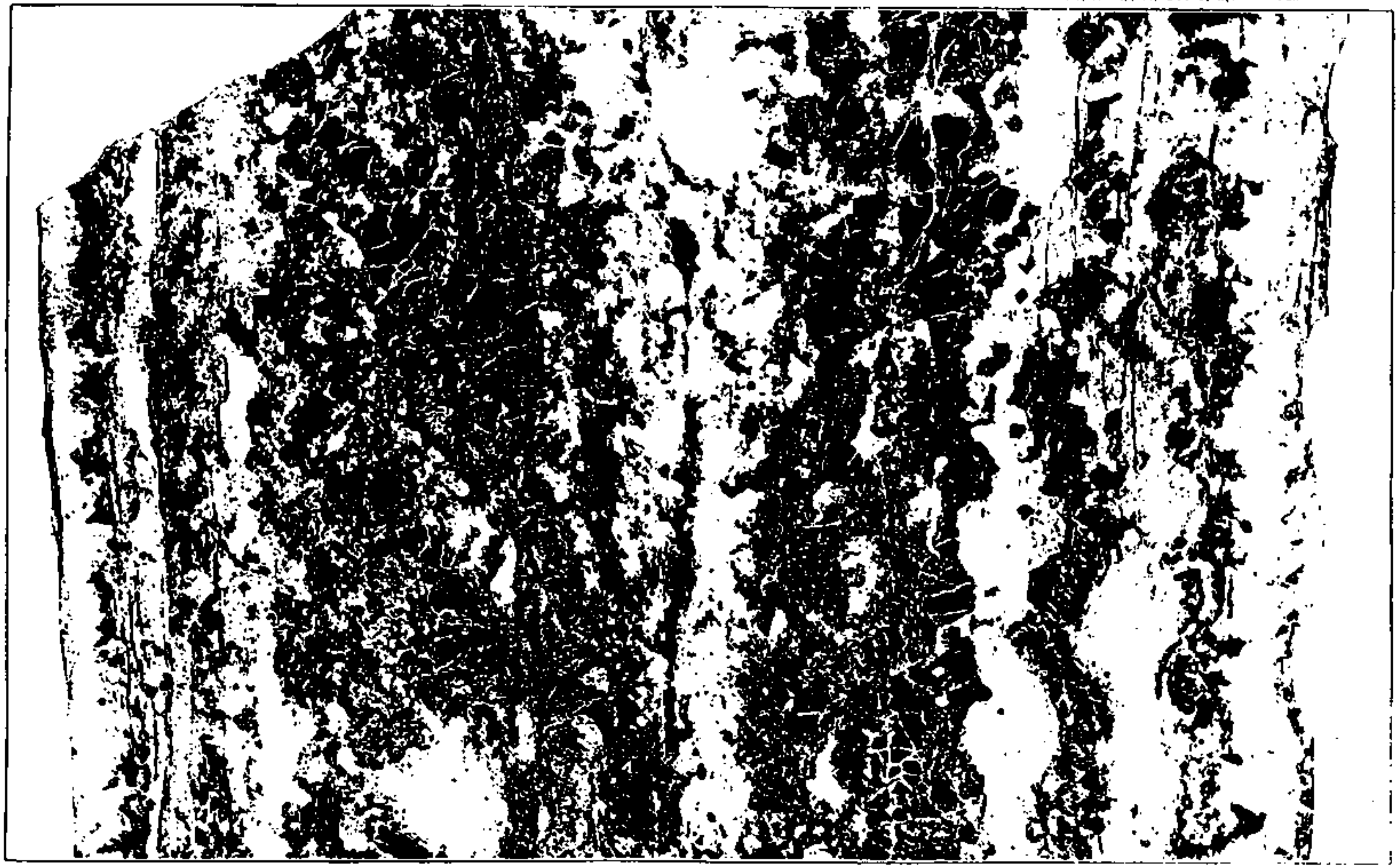
On the northwestern slope of Telescope Mountain, north of C. H. C. Hill, are several northwesterly fissures, usually with steep southwest dip. The two upon which are located the Golden Rod and Leap Year claims are strong and persistent fractures.

Northwesterly fissures also prevail in Horse Gulch, but they are poorly exposed and not at present producing ore. Such are the fissures of the Mohawk, Christina, Belzora, Caledonia, Utah, and other unworked prospects. They are prominent also in the Little Leonard mine in monzonite on the eastern slope of Expectation Mountain.

In addition to the Nellie Bly lode fissure (not the Nellie Bly fault) on Nigger Baby Hill, which has a low northerly dip, nearly east and west, approximately vertical fissures are known in the Lily D. mine, on C. H. C. Hill; in the Calumet mine, north of Piedmont; in the Aztec mine, in Aztec Gulch; in the California and Zulu Chief mines, near the head of Iron Draw; and apparently also in the Eighty-Eight mine, on Silver Creek.

It appears from the foregoing that the northeasterly fissures which have proved so productive in Newman Hill are characteristic of but a limited portion of the district, comprising roughly the southern half of Newman Hill and that part of the base of Expectation Mountain

[1] Loc. cit., p. 118.



SECTION OF A RICH PORTION OF JUMBO NO. 2 VEIN, ENTERPRISE MINE

The ... which embraces the entire width of the vein ...

lying between Sulphur Creek and Iron Draw. Fissures of general northwesterly course, on the contrary, are abundant, not only in Newman Hill but over the entire central portion of the area. Between northeasterly fissures and northwesterly fissures the separation is fairly definite; but between northwesterly fissures on the one hand, and east-west fissures, and in a few cases north-south fissures, on the other, the distinction is less sharp. In the main the fissures are simple and of small or moderate size. With a few notable exceptions they either show no evidence of having been opened by appreciable faulting or else the throw of the fault is small. Thrust faults (i. e., reversed faults) of any importance are not known, and the prevalent dislocation has plainly been normal in character.

STRUCTURE AND MATERIAL OF THE LODES.

The northeasterly fissures of the southern half of Newman Hill are usually occupied by simple fissure veins of banded ore, confined between sharply distinct walls of sandstone or shale. The general appearance of such a vein is shown in Pl. XXVIII, *B*, from a photograph of the Jumbo No. 3 vein (Enterprise mine), which at the point chosen for illustration has a width of nearly 3 feet, but is poor in ore. The veins are usually "frozen" to their walls and the presence of gouge is the exception rather than the rule.

The vein filling consists of quartz, rhodochrosite, sphalerite, galena, chalcopyrite, pyrite, together with argentite, proustite, polybasite, and other highly argentiferous minerals. These various minerals have been so deposited within the fissure as to give a pronounced but rather irregular banding to the veins, as shown in Pl. XXX, which is from a section of the Jumbo No. 3 vein, showing a width of 9 inches of good ore. On fresh exposures the alternating bands, in which rose-pink rhodochrosite, white quartz, rosin-yellow sphalerite, and the various metallic minerals are present in different proportions, give to these veins a striking and unusual beauty. No orderly or constant sequence of mineralogical deposition can be determined from the banding. Usually quartz and rhodochrosite, arranged in irregular bands and inclosing more or less pyrite, chalcopyrite, sphalerite, and galena, occur next to the walls; then follow ribbons in which sphalerite and galena predominate; and finally, along the middle of the vein, there is usually a zone of comb structure, or vugs, consisting largely of quartz and of the high-grade argentiferous minerals. The last are particularly abundant in the quartz vugs, which nearly always occur along the medial plane of the vein, and sometimes along planes near the wall.

In most cases the filling of the northeasterly fissures from the walls to the medial zone of vugs appears to have been a continuous process; but in other instances the fissure, after having once been filled, has been slightly reopened along one or both walls and the resulting space freshly filled, usually with practically barren quartz. This is illustrated in Pl. XXXI, also from the Jumbo No. 3 vein. The vein, here 4½ inches wide, appears to have undergone two or more successive reopenings, each to the width of about half an inch.

Although the northeasterly lodes of Newman Hill are typified by the simple fissure vein, yet they occasionally split up into more complex forms, such as sheeted zones or stringer lodes. The transformation of the veins to masses of small, irregular stringers, near their junction with the Newman Hill blanket, has already been referred to, and will be more fully described elsewhere (pp. 290-291).

Toward the north the material of the Newman Hill northeasterly veins changes. Such veins as have been followed to the Laura crosscut (see Pl. XXXVI) show a notable diminution in the value of their contents. North of the Laura crosscut lies some ground within which the veins have not been much explored; but a little farther north, in the Pro Patria, Fickle Goddess, and other tunnels, the only northeasterly veins found carry little but quartz and pyrite and are of too low grade to pay for working.

The northeasterly veins exploited in the Cowdrey, Tomale, Argonaut, and Bancroft mines, on the west side of the Dolores River, differ materially in their filling from those in Newman Hill. They contain low-grade argentiferous galena, with much sphalerite and pyrite. The gangue is quartz with no rhodochrosite. These veins are generally small, and adherent, or "frozen," to their walls. They frequently split into small, irregular stringers which die out in the country rock. The striking banded structure of the Enterprise lodes is lacking in these veins of like trend on the west side of the river.

The northwesterly lodes of Newman Hill form a notable contrast to those of northeasterly trend. They are filled with white quartz, sometimes containing pyrite, but never any ore in commercial amounts. As opposed to the usual solidity of the northeasterly veins, entire sections of which, with adhering wall rock, can frequently be taken out as specimens, the northwesterly lodes are almost invariably crushed, and accompanied by seams of gouge. The result of this crushing, in extreme cases, is a loose mass of quartz and clay that can be excavated with pick and shovel.

In the Newman mines, where the northwesterly lodes are better exposed and often less shattered than elsewhere, they frequently show rather complex structure, and are often, properly speaking, stringer lodes (see fig. 41).

A banded structure, in which white quartz alternates with thin, shadowy, gray bands, is common in the more solid portions of the northwesterly lodes, and is represented in fig. 41. The dark bands are partly solidified, thin plates or skins of sandstone or shale. They represent portions of the wall which adhered to the vein already formed

SECTION OF A NARROW PORTION OF THE JUMBO NO. 3 VEIN, ENTERPRISE MINE. NATURAL SIZE upon successive fresh openings. Such reopenings have in some cases been many times repeated. At least five renewed depositions of quartz, separated by thin, shaly partings, were counted in a portion of the James cross vein, in the Newman mines. The average width of these individual veinlets of quartz is about a quarter of an inch.

Passing to the northern part of Newman Hill and to the northern slope of Dolores Mountain, the more westerly lodes, which there predominate in the Union-Carbonate and Forest-Payroll mines, show less crushing or shattering. They have also furnished a little ore. The Forest lode is composed of about a foot of quartz and low-grade sphaleritic ore. The latter occurs only in bunches.

On the northern spurs of Blackhawk Peak, the Little Maggie and Alleghany lodes, which also have a northwesterly course, are simple fissure veins, but are so deeply oxidized that their original filling and structure can only be surmised. The Blackhawk lode itself is difficult to describe or define, as it apparently consists of several nearly parallel veins of quartz, forming part of the Blackhawk fault zone. These veins are composed of practically barren, massive quartz, showing no peculiarity of structure. There are no other accessible workings on this lode until C. H. C. Hill is reached, where its probable extension, the Pigeon lode, is encountered in the Logan and Pigeon mines. Here it greatly resembles the northwesterly lodes of Newman Hill, but is on a much larger scale. Where seen in the Pigeon crosscuts, it shows a width of 40 feet and consists of several stringers of quartz and pyrite separated by sheets of country rock. Some of the individual veins of this sheeted zone are 5 feet wide, composed of white, barren quartz and numerous vugs. The whole lode is greatly shattered and is accompanied by much soft gouge. In the Logan workings, the lode shows a width of 12 feet and contains masses of soft, crumbling pyrite. Neither the Blackhawk nor the Pigeon lodes carry any workable ore as far as known, although some appears to have been extracted from that portion of the fissure which traverses the Uncle Ned ground, on Telescope Mountain.

The C. V. G. lode, at Burns, not now accessible, is probably the same as the Pigeon. The A. B. G., on the west side of the river, is a strong vein up to 6 feet in width, carrying streaks of galena, sphalerite, and pyrite in a gangue of quartz and calcite. The vein is accompanied by considerable gouge, indicating movement which probably accounts in part for the structural fault shown on the map (Pl. XLI).

On Nigger Baby Hill the northwesterly fissures are distinguished by an entirely different type of vein from those on Newman Hill. They are prevailingly simple fissure veins of moderate size. In their upper portions they have undergone decomposition of a kind to be more fully described hereafter, but in their deeper, unoxidized portions these veins contain a relatively low-grade sphaleritic ore in a calcite matrix or gangue. Quartz is either wholly lacking or is very subordinate in amount. The calcite varies in coarseness of crystallization. The coarser varieties, showing distinct cleavage faces of dull white or slightly pinkish calcite, were noted in the Iron lode and the Butler No. 2 vein. Finer-grained facies, often slightly yellowish in tint and closely resembling in texture an ordinary limestone, occur in the Phœnix and main Butler veins. The character of the gangue, however, often varies from place to place in the same vein. The proportion of ore minerals to gangue is also extremely variable, ranging from nearly barren calcite on the one hand to nearly solid masses of galena, sphalerite, chalcopyrite, and pyrite on the other. Although the mineral rhodochrosite has not been recognized in these veins, there is good reason for supposing the calcitic gangue to be more or less manganiferous.

Banding is well developed in a branch of the Phœnix lode, on the No. 3 level. The vein is here about 4 inches wide, made up of alternating bands of ore and gangue, varying from 0.1 to 1 inch in thickness. It was from the decomposed upper portions of these relatively low-grade calcitic veins that the bulk of the ore from Nigger Baby Hill has been obtained.

Little can at present be learned concerning the structure of the numerous northwesterly lodes of Horse Gulch, owing to the abandonment of most of the workings upon them. The lodes of the Mohawk, Zenith, and Marriage Stake claims contain practically no vein filling, but are zones of silicification and of impregnation by pyrite, along fissures in monzonite-porphyry. The dump of the Lackawanna shows that this prospect followed a lode containing abundant manganiferous carbonate. Most of the Horse Gulch lodes evidently contained much pyrite, in association with which occurred bunches of saleable ore.

Development on the northwesterly lodes lying north of C. H. C. Hill is not such as to afford much information in regard to their structure. The Leap Year lode, in places 15 feet wide, is in part a silicified breccia zone in sandstones and shales, and in part a stringer lode. It contains a little pyrite and an occasional bunch of galena in much white quartz. The Hureka vein, consisting of about a foot of white, somewhat cellular quartz next the foot wall, and 2 or 3 feet of crushed rock, iron oxide, and clay next the hanging wall, has been superficially prospected and found to contain a little gold. The Golden Rod is a large quartz vein containing numerous fragments of country rock, with pyrite and bunches of galena ore.

Northwesterly fissures are abundant in the Little Leonard mine on Expectation Mountain, but they contain little besides soft gouge.

The structure and filling of the nearly east-west lodes of the Nellie Bly lode fissure, on Nigger Baby Hill, are found to be in every way similar to those of the northwesterly veins on the same hill, such as the Hope or Grand View. The Last Chance lode, lower down on the south slope of the hill, is an irregular fissure vein between walls of altered porphyry, impregnated with pyrite. The vein itself is composed of quartz, pyrite, and chalcopyrite. The Aztec lode, supposed to be on the line of the Nellie Bly fault, consists of banded quartz, about 3 feet in width where seen, accompanied by much crushed and mineralized country rock on each wall (see fig. 62, p. 365). The quartz vein, which apparently owes its banded structure in part to repeated openings and fillings of the original fissure, contains no ore. On the south or foot wall the vein is accompanied by a breccia zone, about 2 feet in width, of mineralized calcareous shales. These pass, with no distinct wall, into less disturbed beds of shale and limestone, which are partly replaced by pyrite and traversed by small stringers of quartz for a distance of 5 feet or more. A very similar breccia, at least 5 feet in width, occurs on the hanging wall, and contains bunches of ore, consisting of pyrite, chalcopyrite, galena, and sphalerite. In the Zulu Chief mine, near the head of Iron Draw, a lode is cut, exhibiting a structure similar to that of the Aztec (see pp. 364–365). It is likely that the two occupy the same fissure. The Calumet lode, supposed to correspond to the Last Chance fault, is a large irregular vein up to 5 feet in width, filled with quartz containing bunches of pyrite. There are no regular walls to the fissure, and the country rock is much decomposed. The whole lode is crushed and disturbed by recent movements.

The foregoing résumé shows that, taking the region as a whole, fissures of like trend are not necessarily characterized by similar ores or by corresponding structures. The miners who first worked in Newman Hill were naturally struck by the contrast between the local richness of the northeasterly veins and the poverty of the northwesterly fissures. They distinguished the two as "pay veins" and "barren veins," and this terminology has obtained a certain currency throughout the district. The adoption of richness and poverty as criteria for classifying the lodes of the region is misleading, particularly as different portions of a single lode would thereby frequently be placed in supposedly distinct classes.

CHANGES IN THE ORE WITH DEPTH.

There are probably few more striking features connected with the Rico ore deposits than the very limited vertical range of the ores. With the exception of the Little Maggie and Alleghany veins, and those of Newman and Nigger Baby hills, none of the lodes in the district have produced much ore, or have been explored to any considerable depth. Such ore as has been found occurred in isolated pockets, or is so low in grade that the various spasmodic attempts to work it have been successively abandoned. Low-grade pyritic ores extend to greater depths than are anywhere reached in the district, but no success has yet attended attempts to exploit them. In the cases of the Little Maggie, Alleghany, and Nigger Baby Hill lodes, the lower limit of the workable ore has thus far been found to correspond with the bottom of the zone of oxidation. The rich ore is here due to purely secondary processes, which will be described in a later section.

In the northeasterly lodes of Newman Hill, however, there is a most decided change, which antedates all superficial oxidation. Unlike secondary enrichments due to ordinary oxidizing processes, the depth at which the Newman Hill veins change their character bears no relation to the topographic surface, but is more or less constant with reference to an overlying blanket. For a maximum distance of about 150 feet below this blanket (the Newman Hill "contact") the northeasterly lodes contain pay shoots of rich ore, such as has been described on pages 261–262. Below this depth the valuable silver minerals disappear; galena, sphalerite, and rhodochrosite vanish; and the veins, which above produce ore carrying many hundred of ounces of silver per ton, change to practically barren quartz and pyrite. So far as their material is concerned they become indistinguishable from the northwesterly lodes. The practical reality of this change is well brought out in the series of longitudinal sections through the veins of the Enterprise mine, shown in Pl. XXXVII. In the Lexington tunnel, which crosscuts the Newman Hill lodes at depths varying from 350 to 550 feet below the blanket, they are found to be small and practically barren, consisting of quartz and a little pyrite.

OXIDATION OF THE ORES.

In the southern part of Newman Hill, as no lodes are worked above the Newman Hill blanket, and as the latter is protected from the free access of surface waters by an impervious bed or "roof" of shale, oxidation has played but a minor part in the development of the ore bodies. In the Union-Carbonate mine some oxidized ore was mined from a northwesterly fissure. This ore was near the surface and extended to a depth of 30 or 40 feet below an overlying blanket, also oxidized. On Nigger Baby Hill, however, and in the Little Maggie and Alleghany lodes, descending surface water has been the effective agent in producing workable deposits of ore.

The depth to which oxidation has penetrated in Nigger Baby Hill is apparently variable. Owing to the steep sides and faulted structure of the hill the permanent ground-water surface is low, and oxidation has probably nowhere extended down to it. The process has been irregularly limited by very local physical and chemical factors and by time. Judging by the extent of the old stopes it appears probable that complete oxidation extends for about 200 feet from the present surface of the hill near its summit, growing less on its flanks.

The process of decomposition was undoubtedly greatly facilitated by the fact that the veins contain a calcitic and not a quartzose gangue. In the initial stages of alteration the impure calcite, containing more or less carbonate of manganese, turns yellowish and is speckled with black dots consisting chiefly of oxide of manganese. As the process goes on these become more numerous and the vein is traversed by soft seams of hydrous oxides of iron and manganese. Finally all original structure disappears and the once solid vein becomes a soft mass which, when seen underground in the moist condition, is black and sooty, but which dries to various dark-brown tints. A chemical analysis of some of this material from the Nellie Bly vein is given below. The substance dries to a very dark-brown powder, soiling the fingers like soot.

It was prepared for analysis by passing through a coarse screen, whereby some irregular quartzose particles were removed, leaving a fairly homogeneous powder.

Chemical analysis of oxidized material from Nellie Bly vein, Nigger Baby Hill.

[W. F. Hillebrand, analyst.]

Constituent	Per cent
SiO_2	15.25
Al_2O_3 with a little P_2O_5 and TiO_2	5.73
Fe_2O_3	13.42
MnO_2	33.77
ZnO	4.75
CaO	2.58
MgO	.97
H_2O at 110° C. H_2O above 110° C	22.81
CuO, CO_2, alkalies, etc	.72
Total	100.00

The foregoing analysis shows that the material is composed chiefly of the hydrous oxides of manganese and iron. The silica is probably present principally as quartz in loose, spicule-like bunches of minute crystals and partly as a hydrous silicate of alumina. The zinc oxide has resulted from the oxidation of sphalerite. The striking features brought out by the analysis are the small amount of lime left in the formerly calcareous vein and the large quantity of manganese present. Although typical, as far as appearance goes, of the oxidized vein matter of Nigger Baby Hill, this particular sample is plainly not an ore.

Not all of the oxidized portions of these veins are workable, but only those in which silver, either native or as cerargyrite or embolite, and sulphate, carbonate, or oxide of lead have been concentrated. Such rich portions are often detected by the presence of small bright specks of malachite or azurite.

The alteration of the upper portions of the Little Maggie and Alleghany veins has been somewhat similar to that described. The Little Maggie vein, however, seems to have contained more copper than is present in the Nigger Baby Hill veins, and some residual kernels of pink rhodochrosite were noted.

RELATION OF THE LODES TO THE STRUCTURAL FAULTS.

In their work on the general geology of the Rico region Cross and Spencer found the structure of the district to be greatly complicated by faulting, the displacement in some cases amounting to several hundred feet. Owing to the frequent concealment of outcrops by landslides and wash these faults are often very poorly shown on the surface, and to properly delineate and interpret them constituted a highly complex geological problem. The solution of this problem, as indicated on the geological map (Pl. XLI), reflects high credit upon these investigators.

Upon taking up the study of the lode fissures, the question of their possible relations to the important structural faults established by the geological mapping was naturally considered. It was found that the connection between them is neither so close nor so obvious as on a priori grounds might be expected.

The productive lodes do not occur in the fissures of considerable faults. Out of the 50 or more fault fissures drawn upon the geological map not one has been shown to contain any large bodies of ore. The Blackhawk lode, which does not itself contain workable ore so far as known, is very close to a large fault, but it is by no means certain that it fills the actual fault fissures. The same might be said of its probable continuation, the Pigeon lode, in C. H. C. Hill. The A. B. G. lode at Burns is possibly on a branch of the Blackhawk fault. It contains some low-grade ore, which, however, has never been worked on a commercial scale. The Nellie Bly fault certainly does not coincide with the Nellie Bly vein, but appears as a close, inconspicuous fissure a few feet south of the latter. It is possible that the western extension of this fault passes through the Aztec and Zulu Chief lodes, but these properties can scarcely be classed as productive. The Last Chance fault, although taking its designation from a prospect of that name, is certainly not identical with the Last Chance lode fissure. It is shown on the map as passing through the workings of the Calumet, an unproductive prospect on the west side of the river.

The question of the coincidence of faults and lodes may be justly summed up in the statement that the most productive lode fissures of the district show very little faulting along them while fault fissures of sufficient extent to be structurally important contain little or no ore. It is but fair to remark, however, that the fault fissures have been scarcely prospected.

Considerable structural faults may also be important in displacing lodes which they cross. It is highly probable that the Deadwood fault, south of Newman Hill, cuts off the Newman Hill blanket and lodes, throwing their southern continuations downward and westward. A zone of faults passing down the west slope of Dolores Mountain, past the Laura shaft, has probably offset the same lodes on the north. Neither of these points, however, could be determined underground at the time of visit.

The Nellie Bly fault, which passes over the nose of Nigger Baby Hill and brings up the massive limestones of the medial division of the Hermosa on the south until they abut against the Rico beds on the north,[1] passes through the workings of the Grand View and Iron mines, without, as far as can be seen, interrupting the Phenix, Grand View, or Iron veins. It seems necessary to conclude that these veins are of later origin than the fault.

RELATIVE AGES OF THE LODES.

The question of the relative ages of the northeasterly and northwesterly lodes of Newman Hill is of theoretical and practical importance. Farish[2] and Rickard[3] have both discussed it, and reached conclusions not entirely in harmony. Farish, after describing the relations observed by him, says:

A consideration of these irregularities naturally suggests a speculation concerning the relative ages of the two vein systems. In this connection I must confess that, from the complexity of the problem, I have not been able to arrive at positive conclusions. Reasoning from the occurrence of the sharp faults in the "vertical pay veins"—the dislocation being absolute—and the unbroken trend of the "cross veins," the inference would be drawn that the latter are, relatively, the younger. Whatever mistrust arises from such a deduction is occasioned by the observed deviation of the "vertical pay veins" from their normal course for considerable distances to a parallelism with the intersecting "cross veins" within the walls of the latter. On the assumption, however, that all of the "vertical pay veins" when disturbed by intersecting "cross veins" were originally faulted, and that the faulting fissure in some instances—prescribed by local influences—furnished a connecting channel for the mineral solutions circulating in the faulted vein, these phenomena are susceptible of reasonable interpretation. I am at least strongly inclined to favor this view.

Rickard, on the other hand, maintains that the northwesterly fissures are younger than the northeasterly lodes, and that the described

[1] See Cross and Spencer, loc. cit., p. 118. [2] Loc. cit., pp. 158-160. [3] Loc. cit., pp. 946-952.

deviations of the latter into the former are simply cases of drag, due to faulting.

Neither of the foregoing hypotheses is entirely satisfactory, although both contain partial truths. Neither Farish nor Rickard appears to have given due consideration to the various facts which must be included in any complete explanation. The observed phenomena that bear upon the question may be briefly summarized as follows, the reader being referred to the detailed accounts of the Newman Hill mines for their fuller description:

(1) The lodes of the two systems are distinctly different in trend (see Pl. XXIX).

(2) The northwesterly lodes are practically barren, whereas the northeasterly veins usually contain rich ore to a depth of about 150 feet below the Newman Hill blanket.

(3) The northeasterly veins sometimes show a later generation of quartz and pyrite.

(4) The northwesterly lodes, when not too much crushed, usually show banding due to repeated openings and fillings.

(5) The northeasterly veins are solid and often adherent to their walls; the northwesterly lodes are almost invariably crushed and accompanied by gouge.

(6) The northwesterly fissures generally cross the others without being themselves deflected.

(7) In some cases the northwesterly fissures fault the northeasterly lodes, but more commonly they pass through the latter without offsetting them. Marked changes in the value of the ore are said to occur at such crossings.

(8) A northeasterly vein is sometimes lost at the crossing of a northwesterly lode, as was the case with the Hiawatha on the 100-foot level of the Enterprise mine (p. 320) and the Chestnut and Newman veins in the Newman mines (pp. 332–334). It has been commonly assumed in such cases that the northeasterly vein has been faulted and offset for distances up to 175 feet. It is to be noted that the northeasterly vein is not always sharply cut off at the supposed fault, but small stringers are sometimes present, continuing on beyond the latter. Furthermore, the supposed offset of any one of the northeasterly veins cut by a northwesterly fissure is not always comparable in amount with the offset of the neighboring veins cut by the same fissure. Thus Rickard's diagram (fig. 47, p. 320) shows a northwesterly fissure offsetting the Hiawatha vein about 175 feet and the adjacent Songbird vein only 20 feet, both being nearly vertical veins.

(9) Northeasterly veins sometimes contract or divide into small stringers upon approaching a northwesterly lode (see fig. 51, p. 332).

(10) None of the lode fissures displace the overlying blanket more than 25 feet, most of them much less than this.

(11) In one case (that of the Jumbo No. 3 vein, Enterprise mine; see p. 321 and fig. 49) a northeasterly vein is known to turn into a northwesterly fissure for a short distance and then resume nearly its normal course. The deflected portion of the vein has been brecciated, and subsequently healed by white quartz, which was later shattered in its turn. In a few rare instances small northwesterly fissures have been observed occupied by the characteristic filling of the northeasterly lodes.

(12) The Eureka vein pursues a nearly straight course through the principal Newman Hill workings without being offset by the northwesterly fissures which cross it, and which are commonly supposed to have offset neighboring lodes, in some cases as much as 175 feet.

It is believed that the hypothesis which best reconciles the various observed facts is one which supposes the initial fractures, both northwesterly and northeasterly, to have been formed at practically the same time. Studies of vein structure in this and other regions show that lode fissures may not open to their full width until some considerable time has elapsed after the production of the first fracture. It is probable that in the network of intersecting and partly incipient fractures in Newman Hill the northeasterly fractures were as a whole the first to open sufficiently to permit vein deposition. If the northwesterly fissures are entirely of later date than the northeasterly veins, it is impossible to account for the fact that the latter occasionally follow the former for short distances, and that they sometimes die out or divide into stringers just as a northwesterly fracture is approached. That the ore changes abruptly in value at the crossing of northwesterly fissures, even where no faulting is perceptible, is strongly insisted upon by the miners and by the present superintendent of the Enterprise mine. It is best explained by supposing that the northwesterly fractures existed when the ore was being deposited in the more open fissures. If the northwesterly fissures were of altogether later date, and simply faulted the northeasterly veins, it should be possible to consistently match the faulted lodes on opposite sides of the dislocation. In many cases this is utterly impossible, for whereas some lodes are found to be slightly displaced and can be recognized and followed, others have no continuation beyond the fissure. Attempts to find and identify such continuations have led to absurdities, such as supposing that a fracture which throws the overlying blanket less than 24 feet and does not perceptibly offset the Eureka lode can offset one lode 175 feet and another, but a few feet away, only 20 feet.

On the other hand, unless it be allowed that the principal opening and filling of the northwesterly lodes was later than the ore deposition in the northeasterly lodes, it is impossible to account for the fact that the former cross the latter, and no good reason appears why both should not have been equally filled with ore. It is probable that the opening and filling of the northwesterly fissures was in part synchronous with the slight reopening and filling with barren quartz and pyrite observed in connection with the northeasterly lodes. It certainly corresponds to the partial brecciation and recementation by barren quartz of that portion of the Jumbo No. 3 vein, which follows a northwesterly fissure, and with the cementation of the fault-dragged fragments of the Swansea vein on the 100-foot level of the Enterprise mine (see p. 321).

Finally the shattered nature of most of the northwesterly lodes, and their constant accompaniment by seams of gouge, show that they have continued to be planes of more or less movement up to recent times. It is consequently impossible to determine how much of the observed moderate faulting along these fissures took place prior to their complete filling with quartz, and how much has taken place during the subsequent crushing of their veins.

If the foregoing view is correct, the development of the Newman Hill mines in recent years, in accordance with the hypothesis that the disappearance of a northeasterly vein at or near a northwesterly fissure is always due to the faulting, and that the faulted portion of the lode may be found offset over 100 feet to one side, has had no reasonable basis. Such a working hypothesis has certainly led to errors and confusion in identifying lodes on opposite sides of the northwesterly fissures. The practical consequences of adhering to this plan, however, have not been altogether disadvantageous, since it encouraged crosscutting, and led to the discovery of veins which were probably, in several cases, *not* the faulted continuations sought for.

It has been assumed in the foregoing discussion that lodes of like trend and similar character are of practically the same age. It is possible, however, that some of the northwesterly lodes may be earlier and some later than the northeasterly vein. While it would be difficult to disprove the latter view, it is not considered probable. Its acceptance would knock away the foundations which underlie systematic treatment of the lodes both on the theoretical and practical sides.

Passing beyond the bounds of Newman Hill, we find that the same age relationship exists between the northeasterly and northwesterly lodes on the west side of the Dolores River, between Sulphur and Iron creeks.

In other portions of the district, however, there is scant opportunity for determining the sequence of lode fissures of different trend. As already noted, the northeasterly lodes are absent or insignificant.

THE BLANKETS.

Enterprise blanket.—Of the various blankets occurring in the Rico district, the so-called Newman Hill or Enterprise "contact" is most important, and will be first described. The others will then be taken up, and their characteristic features so outlined as to emphasize points of resemblance or contrast, with reference to the most prominent type.

The Enterprise blanket is for the most part an unconsolidated breccia, occurring nearly midway between the top and bottom of the series of sandstones, shales, and limestones which make up the lower division of the Hermosa. It underlies the southern half of Newman Hill, but its extent is only approximately known. On the west it should outcrop along the hillside above the adits of the Rico-Aspen, Newman, and Enterprise mines, were it not for the thick cloak of wash which conceals the rock in place. On the east it conforms to the general southeasterly dip of the beds (about 15°), and passes under Dolores Mountain. At a distance of 3,000 feet, measured down the dip from the surface, the blanket becomes thinner; but its full extent in this direction is unknown. On the north it has not been followed far beyond the Laura shaft. Other blankets occur to the north in the Union-Carbonate mine, but none of them have been satisfactorily identified with the Enterprise "contact." On the south the blanket is cut off by the Deadwood fault. As it approaches the latter it turns down with a rapidly increasing southerly dip and passes out of reach from the levels of the present workings.

The blanket has been extensively exploited by the Enterprise, Newman, Rico-Aspen, and other mines, and is estimated to have produced at least a third of the entire output of the district. At present very few known bodies of ore remain, and the "contact" workings (see Pl. XXXVI) have been allowed to cave in.

The blanket rests everywhere upon a bed of limestone, familiarly known as "the short lime," but which may here be conveniently referred to as the *blanket limestone.* This bed varies in thickness from a few inches to about 2 feet. It is light gray, compact, and apparently nonfossiliferous. It effervesces freely with weak acid, and is an ordinary, slightly argillaceous limestone.

Below the limestone are usually found 5 or 6 feet of dark shales, alternating with very thin lenses of sandstone. Under these is generally a second bed of limestone similar to that above, and below this limestone come sandy shales and sandstones, the latter predominating with increasing depth.

The blanket resting upon the blanket limestone varies in thickness from 2 to 20 feet. The average is perhaps 6 feet. It is overlain by fissile, black shale which, so far as known, is never absent, and performs an important function in keeping out, by its imperviousness, the abundant surface waters. Above the shale are beds of sandstone and sandy shale, all more or less fractured and soft, which extend up to the loose surficial material covering the hill. The only workings in these upper beds are the vertical shafts sunk to the blanket below, and as these are necessarily closely timbered, and now mostly inaccessible, there is little opportunity of studying the beds which they penetrate.

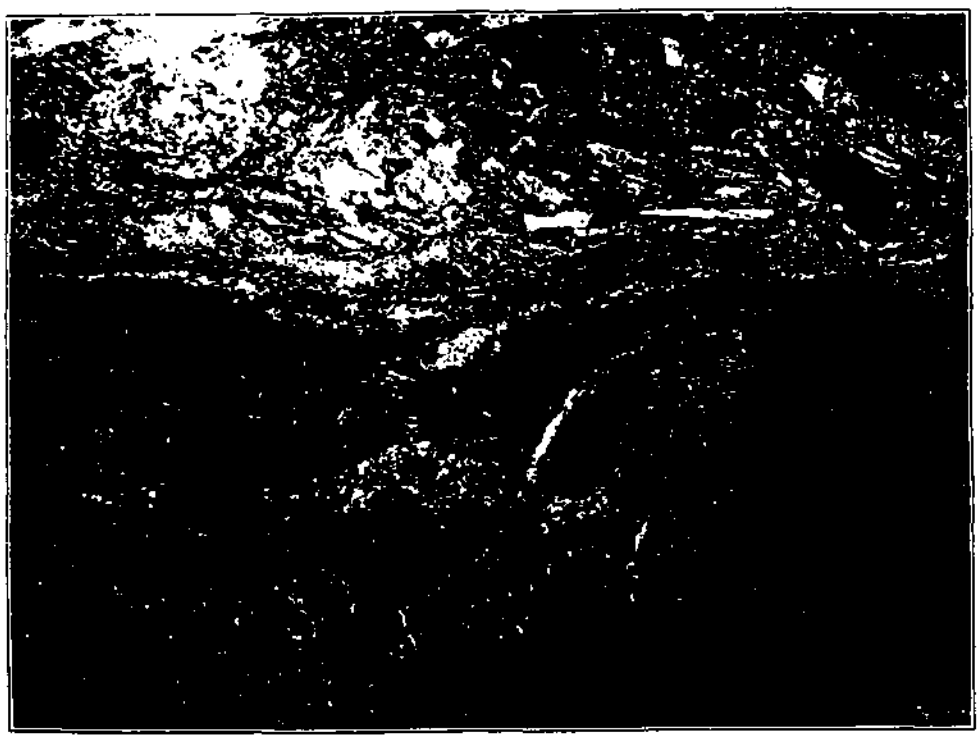
The blanket itself dips with the inclosing beds, generally southerly, at about 15°, but it is warped and irregular (see Pl. XXXVII). For the entire thickness it is sometimes made up of a mass of small shale fragments embedded in a matrix of still more finely comminuted shale particles. This breccia passes upward, with no sharp break, into less disturbed shale, which in its turn grades into the so-called "shale roof." Occasionally fragments of soft sandstone are mingled with the shale flakes in the breccia. When this is the case, the rock immediately above the blanket is usually a bed of the same sandstone, the brecciation having involved the entire thickness of the shale. Seams of gouge show that there has been some movement within the breccia, due partly to faulting parallel with the bedding; but this motion has been local, and the blanket as a whole can not be regarded as a simple friction breccia due to a bedding fault. In structure and general appearance the blanket breccia is perfectly reproduced, artificially, when shale waste is dumped into an abandoned stope and allowed to slightly consolidate.

As a rule the breccia constitutes but the upper part of the blanket. The lower part, resting directly upon the blanket limestone, is commonly a soft, gray, silty material, frequently showing a laminated structure suggestive of water-laid origin. This deposit varies in thickness; and in its upper part is mingled with fragments of shale. Wherever ore occurs in the blanket, it is usually as a replacement of this material, which is evidently the "pulverulent lime" of Rickard.[1]

The foregoing description may be considered as applying to the typical and usual appearance of the blanket. But in some places considerable bodies of gypsum occur above the blanket limestone, occupying more or less of the space usually filled by the blanket. Such a mass occurs in the Enterprise mine south of the Group tunnel, and extends southeastward in the direction of the Vestal and Aspen shafts. It is perhaps continuous with the gypsum said to have been encountered near these shafts in the Rico-Aspen workings. Another large body occurs in the Rico-Aspen mine, near the Silver Glance shaft. The maximum thickness of the gypsum is not now revealed,

[1] Loc. cit., p. 968, and elsewhere.

A. UNDER SURFACE OF GYPSUM BED, SHOWING SOLUTION CAVITIES, RICO-ASPEN MINE



B. BLANKET OF THE NEW YEAR OR GOLDEN FLEECE MINE.

Photograph by G. W. Tower.

but it probably exceeds 10 feet, and may reach 30 feet.[1] It sometimes rests directly upon the blanket limestone with an undisturbed contact of deposition, the latter so close that a knife blade can not be thrust into it. In other places the two rocks are separated by a varying thickness of the gray silty material already described as a characteristic constituent of the lower portion of the blanket. Wherever this occurs, however, the under side of the gypsum shows evident signs of solution. This is well shown in the Rico-Aspen mine, near the Silver Glance shaft, where the photographs were taken from which Pls. XXXII, A, and XXXIII were made. The gypsum is seen to be pitted with rounded, pothole-like cavities up to 8 feet in diameter. Lying upon the limestone under these cavities is always more or less of the gray silty material already noted. The general form of the cavities and the relation of the gypsum to the underlying and overlying beds is shown in fig. 56, p. 337, from a sketch near the Silver Glance shaft. It is reported on good authority that in the old Enterprise workings cavities or "water courses" in the gypsum large enough for a man to crawl through were of frequent occurrence.

There are but few places now accessible where the peripheries of

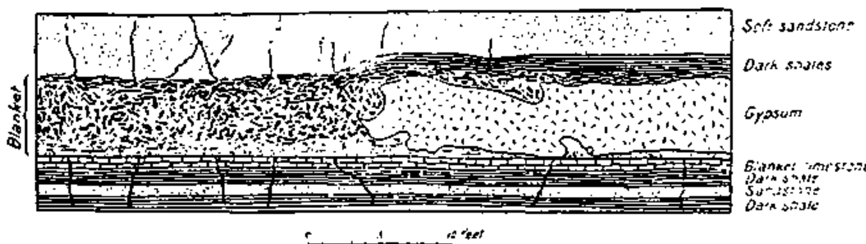


FIG. 42.—Diagrammatic section through a portion of the Enterprise blanket, showing relation of the gypsum to the blanket.

the gypsum masses can be studied. One such point was reached in the Enterprise mine, and the relation of the gypsum to the typical blanket material is shown in fig. 42. The gypsum was found to have the irregular, cuspate forms characteristic of a homogeneous substance wasting away by solution. The unconsolidated blanket breccia fits snugly against the reentrant curves of the gypsum, much as loose morainic material might crowd against the melting front of a glacier. The gypsum is dissolving, and as fast as it dissolves the blanket breccia and the gray silt take its place.

The gypsum, wherever seen, is massive, with an occasional suggestion of schistosity parallel to the general bedding. It is silvery gray on fresh fracture, fine granular in texture, and apparently nearly pure.

[1] Rickard, loc. cit., p. 970, gives the maximum thickness, in the southwestern part of the Enterprise mine, as 15 feet.

A chemical analysis of a sample collected near the Silver Glance shaft is given in Column I of the following table:

Analyses of gypsum from Rico-Aspen mine.

[W. F. Hillebrand, analyst.]

Constituent.	I.	II.
CaO	32.49	17.18
MgO	[a] .92	12.48
SrO	.10	19.49
SO_3	45.07	17.22
CO_2	1.51	26.34
H_2O	19.61	.80
SiO_2	.51	3.50
TiO_2	Faint trace.	....
Al_2O_3	[b] .05	[b] .80
Fe_2O_3	.09	1.62
MnO	......	.09
BaO	......	Faint trace.
Na_2O	Traces.	.18
K_2O		.24

[a] 0.21 per cent as silicate.

[b] With trace of TiO_2, and (in II) of P_2O_5.

No. I also contains a faint trace of some metal precipitable by H_2S.

I. Gypsum, from near Silver Glance shaft, Rico-Aspen mine.

II. Alteration product, or residue, of gypsum, from same locality.

The analysis shows that the gypsum is of fair purity, but probably contains small quantities of dolomite, minute amounts of magnesium, iron, and aluminum silicates, and a very little strontianite or celestite.

In Column II of the table is given an analysis of the gray silty material so characteristic of the lower portion of the blanket, which has evidently been deposited as the gypsum was dissolved. The material chosen for analysis was collected near the Silver Glance shaft, at a point where it forms a layer about 1 foot thick, separating the gypsum above from the blanket limestone below. Samples were taken from the top and bottom of this layer, but they showed so little visible difference that only the lower one was analyzed.

When dry the material resembles a light-gray, dusty earth, sometimes faintly streaked with yellow, probably due to the presence of a little iron oxide. The clod-like lumps in which the substance dries may be easily pulverized between the fingers to a dusty powder, which reveals little or no grit when rubbed on glass. Under the microscope the powder is seen to consist chiefly of minute, colorless, crystalline

UNDER SURFACE OF GYPSUM BED, SHOWING SOLUTION CAVITIES.

grains, rounded in outline, but partly of prismatic habit. There is also an occasional grain of pyrite present.

The chemical analysis shows that this powder is essentially a mixture of dolomite and celestite, about 56 per cent of the former to about 37 per cent of the latter. The iron is probably present partly as pyrite and partly as limonite, or some other hydrous oxide. The alumina, alkalies, and water are very likely combined with the silica to form some unknown silicate or silicates present in minute quantity.

The mass relation between the original gypsum and the pulverulent material analyzed being unknown, it is impossible to closely calculate the gains and losses involved in the partial solution of the gypsum and the accumulation of this less soluble residue. A very large proportion of the original hydrous calcium sulphate, probably over 90 per cent, has been dissolved and carried away, and the analysis of the original gypsum can be compared with that of its residue only after the percentages of the latter analysis have been divided by some number to which it is possible to get but a very rough clew. If the alumina has remained constant during the change, then analysis II should be divided by 26.6. If the strontia has been neither increased nor diminished, then the divisor should be 194.9. These numbers are so different that it is unsafe to assume the constancy of either constituent, or even to employ the mean of the foregoing numbers as a rough approximation to the truth. It is possible that the material analyzed, coming from the bottom of the deposit, is richer in celestite than in the upper portion.

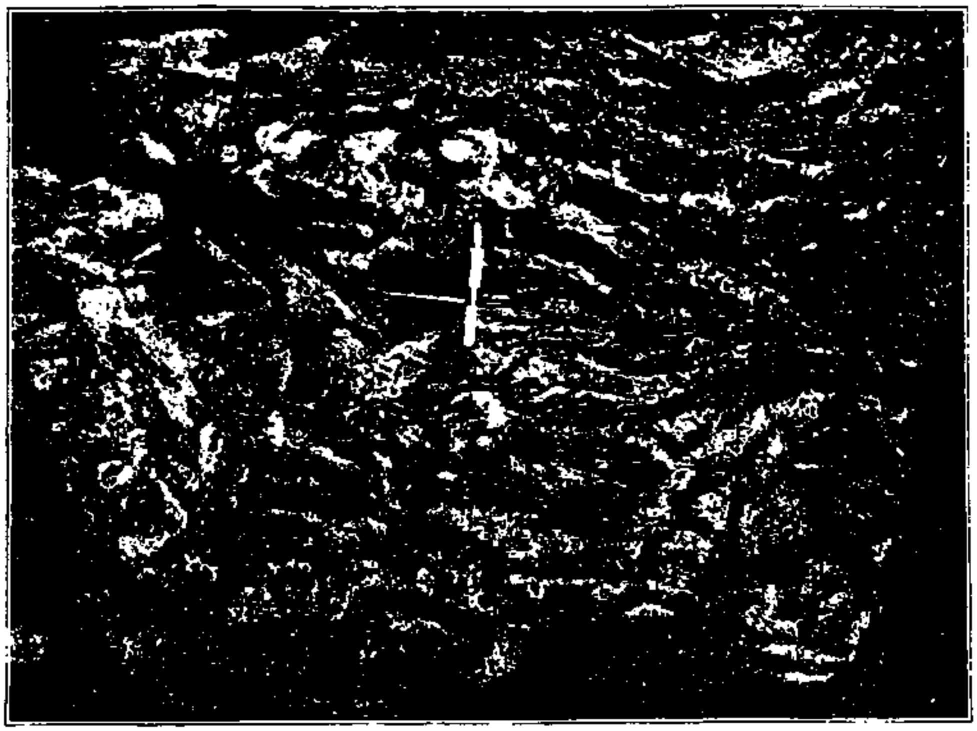
Although the chemical analyses do not suffice for quantitative calculations of losses and additions involved in the change, they bear out the unimpeachable testimony of geological occurrence that the gray, silty mixture of dolomite and celestite is essentially a residue from the solution of the gypsum. This residue, however, may have received some additional strontia from outside sources.

The occurrence of the gypsum in the blanket zone is a matter of more theoretical and practical moment than has hitherto been supposed, and it is important to gain some idea of the former extent of the gypsum and to understand its origin. It has been shown that the gypsum is in process of solution and that this solution is accompanied, step by step, by the accumulation of a silty residue of dolomite and celestite. The existing gypsum masses show characteristic solution forms on their peripheries. The blanket breccia, closely following up the process of ablation, crowds snugly against the wasting gypsum. The peculiar pulverulent mixture of dolomite and celestite, recognized as a product of the solution of the gypsum, is nearly always present in the lower portion of the blanket.

The foregoing facts not only prove that the gypsum once possessed a greater horizontal extent than at present, but they show beyond reasonable doubt that the gypsum was once coextensive with what is now known as the Enterprise "contact," or blanket. The recognition of the fact that the present gypsum masses are mere wasted remnants of a continuous bed that once occupied the entire space now filled by the Enterprise blanket is of more importance for an understanding of the genesis of the ore deposit than is the distinct question of the origin of the gypsum itself.

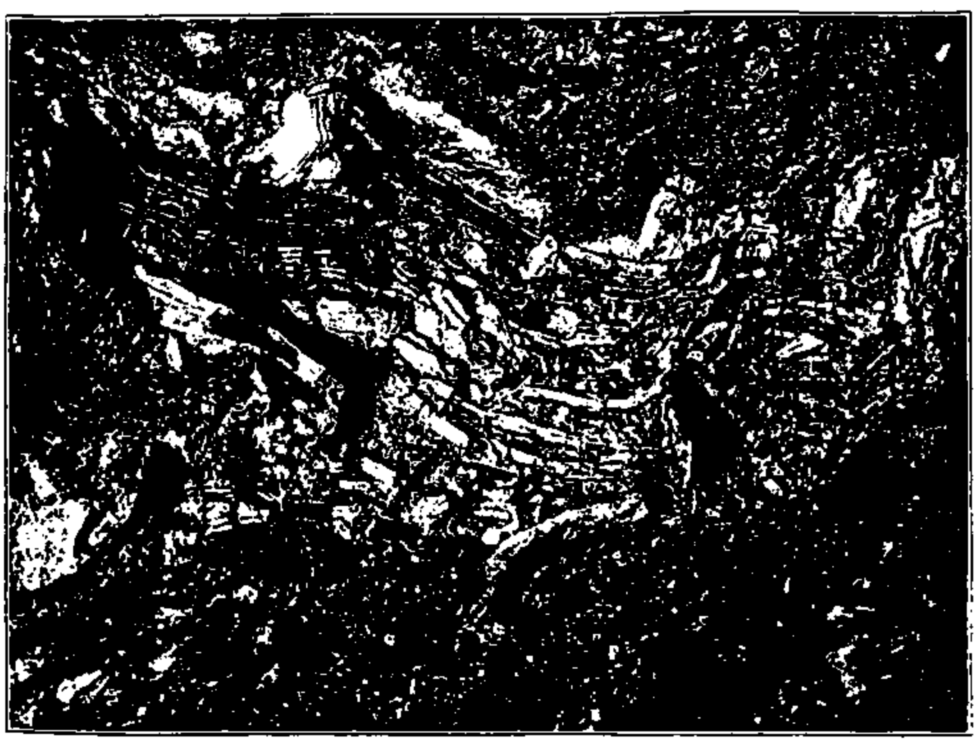
In the paper already quoted Rickard[1] refers casually to the gypsum and suggests that it has been formed "by a sulphatization of lime breccia through the agency of solution coming from neighboring ore-bearing measures." Spencer[2] has called attention to the fact that thick beds of gypsum occur in the corresponding portion of the Hermosa formation in the region of the Animas River, and has suggested that the gypsum of Newman Hill is in reality an integral part of the formation and not a secondary deposit. He has also suggested the possibility of the gray silty material, which he somewhat inaccurately terms "marl," being a residue left after the solution of the gypsum—a hypothesis which has just been shown to be well founded. That his view of the gypsum is in the main correct admits of no doubt. The fact that beds of gypsum are known to occur in the Hermosa formation a few miles away is alone strong presumptive evidence that the Newman Hill gypsum is an original member of the formation and dates from Carboniferous times. Wherever its under side is not pitted by corrosion it rests snugly upon the blanket limestone as a sharply distinct bed.[3] The formation of gypsum from limestone by the action of sulphate solutions is a process chemically possible, and one which is actually in progress in C. H. C. Hill. But the gypsum so formed is merely a dull, earthy crust on the limestone, is evidently dissolved nearly as fast as it is formed, and attains no considerable mass. The massive crystalline character of the Newman Hill gypsum and its purity render unlikely the hypothesis of its derivation from a sulphatized argillaceous and siliceous limestone. Such a hypothesis is made yet more improbable by the fact that the gypsum is now wasting away at a rate which would never have allowed it to accumulate in the first place through the chemical process suggested. Lastly, it is inconceivable that a mass of limestone from 10 to 30 feet in thickness should have been completely altered to gypsum, while the blanket limestone immediately below it shows no trace of such action. No such massive bed of limestone as is required by this hypothesis is known elsewhere in the beds of the Lower Hermosa, and the idea of metasomatic origin may safely be dismissed as a gratuitous

[1] Loc. cit., p. 970.
[2] Cross and Spencer, loc. cit., pp. 53 and 111.
[3] The statement of Spencer (loc. cit., p. 111) that the gypsum, "wherever it occurs, rests above the pulverulent limestone of the 'contact,'" is true only where more or less solution has taken place.



A. [illegible]ICIFIE[illegible] SHALE BRE[illegible] [illegible] THE ENTERPRISE BLA[illegible]KET, ABOVE THE JUMBO[illegible] VEIN.

[illegible] by G. W. [illegible]



B. UNMINERALIZED PORTION OF THE MAIN BLANKET, UNION-CARBONATE MINE

Photograph by G. W. Tower.

suggestion. The Newman Hill gypsum was originally a bed laid down with the Hermosa shales, sandstones, and limestones. There are strong reasons for supposing that it was lenticular in form and may not have extended far beyond the present bounds of Newman Hill.

The blanket as thus far described, consisting of shale breccia and of pulverulent dolomite and celestite, has been locally modified through processes connected with ore deposition. The results of these processes may be classed as (1) silicification and (2) deposition of ore. Both of these modifications are directly connected with the lode fissures, and occur where the latter meet the blanket. Although closely related, silicification and ore deposition appear to have been to some extent antagonistic or mutually exclusive processes. The silicification sometimes involves the whole thickness of the blanket and even part of the blanket limestone. It is well shown in the Enterprise mine, in the so-called Bridal Chamber (Pl. XXXIV, *A*), above the intersection of the Jumbo No. 3 vein with a large northwesterly lode, and in the Rico-Aspen mine above the intersection of the Montezuma vein with two northwesterly lodes. In both these places all of the finer material of the blanket has been replaced by pure white quartz. The larger fragments have also been silicified, but can still be recognized as dark patches in the quartz. An example of such silicified dark shale is shown in Pl. XXXV. In this case the shale was only partly brecciated prior to silicification, and the specimen still shows a rough banding parallel to the original stratification. A chamber freshly excavated in such material presents a striking and beautiful appearance. Under the microscope, in thin section, the former shale fragments, in spite of their retention of dark color, are found to be altered to a finely crystalline mosaic consisting almost wholly of quartz.

Workable ore is sometimes associated with such a silicified blanket, but more often as silicification becomes prominent the ore vanishes, or vice versa.

The blanket ore occurs chiefly as a replacement of the pulverulent lower part of the blanket above both the northeasterly and northwesterly lodes; but it sometimes extends up into the breccia, where it may perhaps have formed partly as the filling of interstitial spaces, as well as by replacement. It frequently partly replaces the blanket limestone, particularly where the latter is brecciated. No large bodies of "contact" ore could be seen at the time of visit, in 1900. In the southern part of the Rico-Aspen mine, above the Selenide vein, no ore is found where the gypsum occupies the usual place of the blanket, but it does occur farther north, where the gypsum has been dissolved away. In the vicinity of the Vestal shaft, however, and in portions of the Enterprise mine, ore is said to have occurred in the gypsum itself. A little of this ore was seen in the Enterprise in 1900. It occurs as irregular bunches in the lower part of the gypsum, having metasomatically replaced the latter. Such ore has a gangue of quartz, rhodochrosite, and selenite.

The usual blanket ore of the Enterprise and Rico-Aspen mines is similar to that of the northeasterly lodes, but presents certain differences which are always sufficient to identify it. It is usually less solid, and shows less regular banding, or none at all. Rhodochrosite is not so abundant as in the lode ore. The blanket ore consists of galena, sphalerite, and one or more rich silver-bearing minerals, in a quartz and rhodochrosite gangue which is often subordinate in amount. With the foregoing minerals are usually associated comparatively small amounts of chalcopyrite, and sometimes argentiferous tetrahedrite. Common pyrite is apparently very subordinate in the rich blanket ore. The rich silver-bearing minerals which have been identified include polybasite, in characteristic tabular crystals, argentite, proustite, and probably stephanite. Possibly other minerals also occur, but their exhaustive collection, isolation, and identification would constitute a special investigation.

Many other blankets occur in the Rico district, some ore bearing and some not. As a rule miners working claims on these blankets have a more or less confirmed belief that they are "on the Enterprise contact." Most of these "contacts," it is true, are in rocks belonging to the lower division of the Hermosa, and some of them may occur at the same stratigraphic horizon as the Enterprise blanket. But there entered into the formation of the latter certain conditions which increased its ore-bearing capacity and which appear to have been absent in the formation of all other blankets examined. The exact nature of these differences will be partly understood from the following descriptions and will be particularly dwelt upon in the section on the origin of the ore bodies.

A small blanket, of limited horizontal extent, is known in the Enterprise workings from 100 to 150 feet below the main "contact." It is a breccia of dark shale, which carried a little ore alongside of the Enterprise vein. The gray, silty material, characteristic of the main blanket, was not noted in this lower breccia zone, which, however, was seen only in the main tunnel.

New Year blanket.—Still lower in the stratigraphic series, and fully 400 feet below the main Enterprise blanket, is that of the New Year mine (Pl. XXXII, *B*). This is a strong zone of brecciated shales, resting upon an intrusive sheet of porphyry and overlain by soft shales. The blanket shows evidence of considerable differential movement between the overlying and underlying rocks. It is partly silicified and contains some low-grade ore. The monzonite-porphyry which underlies it is probably the same massive sheet encountered in the Skeptical shaft, at the bottom of the Jumbo shaft, and in the bore-hole driven below the Rico-Aspen workings.

SILICIFIED SHALE BRECCIA FROM THE ENTERPRISE BLANKET NEWMAN HILL NATURAL SIZE.

Cowdrey, Bancroft, Silver Swan, and Little Maggie blankets.—On the west side of the Dolores River, "contacts" occur in the N. A. Cowdrey, Bancroft, Little Maggie, and Silver Swan mines. These are all in Lower Hermosa rocks, but occur at various horizons. The N. A. Cowdrey blanket consists of two members of disturbed black shale, separated by a bed of limestone about 3 inches thick. The entire blanket is underlain and overlain by massive sandstone. Some low-grade ore occurs near the bottom of the lower shale at its intersection by a lode. The Bancroft blanket consists of soft shale breccia, mixed with clay, which rests upon massive sandstone and is overlain by shale. It is from 2 to 3 feet in thickness. In the Silver Swan mine a blanket consisting of about 6 inches of soft, gray clay or gouge passes upward into an unknown thickness of brecciated black shale. In the Little Maggie the principal blanket consists of dark shale breccia resting upon a bed of limestone and overlain by shale. It more closely resembles the Enterprise blanket than do the brecciated zones of the other mines, but none of the pulverulent mixture of dolomite and celestite was observed. This breccia contains small bunches of low-grade ore, but has been little explored. Several incipient or local "contact" breccias occur at various horizons in the dark shale of this mine.

Union-Carbonate blankets.—In the Union-Carbonate mine, on the north spur of Dolores Mountain, several blankets are known, none of which, in spite of their proximity and the fact that they occur in Lower Hermosa rocks, can be satisfactorily identified as the Enterprise blanket. The principal ore-bearing "contact" of this mine is composed of a zone of breccia resting upon a sheet of intrusive porphyry. It is sometimes overlain by porphyry and sometimes passes upward into relatively undisturbed shales. It has a thickness of 4 or 5 feet and in its less altered condition consists of somewhat mineralized fragments of shale and porphyry (Pl. XXXIV, *B*). The shale is often bleached nearly white and is partially replaced by ore, as described on pages 344–345 and illustrated in fig. 60, page 345. But where certain fissures intersect the blanket the latter, for a varying distance on each side of the line of intersection, is entirely replaced by masses of quartz and pyrite containing considerable bodies of low-grade ore.

Below the blanket just described occur several smaller and less important ones of different character. These are found in beds of dark shale, particularly in thin beds lying between relatively massive beds of sandstone or sheets of porphyry. When fully developed these blankets consist of a plastic yellow clay. The clay is an alteration product of the shale in place and often preserves traces of the original shaly lamination. Its yellow color is mainly due to hydrous oxide of iron, which readily dissolves in hydrochloric acid, leaving an apparently amorphous white residue the exact nature of which can be determined only by quantitative chemical analysis. It is not known whether this clay represents a direct alteration of the shale or whether it is due to the oxidation of some zone of alteration originally different in character. The alteration does not always involve the entire thickness of a bed of shale, but often constitutes a medial zone grading above and below into ordinary dark shale. The position and extent of this zone within the bed are probably dependent upon some variation in the composition of the latter. These clayey zones sometimes contain bunches of oxidized ore near intersecting vertical fissures.

Forest-Payroll blankets.—In the Forest-Payroll mine, about 1,000 feet northeast of the Union-Carbonate, there are two blankets from 30 to 50 feet apart, neither of which has as yet been identified with any of those of the Union-Carbonate mine, although, like the latter, they lie in strata belonging to the lower division of the Hermosa.

The lower blanket is about 5 feet in thickness. It is a breccia of shale, mingled with yellow clay, and resembles some of the blankets of the Union-Carbonate mine. It is underlain by sandstone and overlain by shale. The blanket is not a simple breccia throughout, but the softer, brecciated, clayey layers are sometimes separated by harder beds of shale or sandstone which have resisted the change undergone by the more susceptible beds and preserve in some measure their firmness and continuity. This blanket contains some rather low-grade ore where intersected and slightly faulted by nearly vertical northwesterly fissures. A little galena is found, but the ore is usually oxidized.

The upper blanket is 5 or 6 feet in thickness and rests sometimes on shaly, calcareous sandstone, sometimes on a sheet of porphyry. It is overlain by disturbed and broken shales. In its general appearance this blanket is similar to the lower one, but it contains irregular masses of limestone which bear much the same relation to the blanket that the gypsum bears to the Enterprise "contact." In some places the limestone occupies the entire thickness of the blanket, extending from the porphyry or sandstone floor up to the shale roof. It is often traversed by irregular fissures, filled with a black, sooty material, which is also very abundant throughout the blanket and is very like the product from the Nellie Bly vein, of which a description and an analysis are given on page 267. In other places the limestone is entirely absent, or occurs in isolated masses of exceedingly irregular form which are always covered with the black substance described and are embedded in the soft material of the blanket. The limestone, light buff in color and evidently impure, is finely granular in texture and is minutely banded or laminated parallel to the general bedding of the inclosing sediments. The sooty material is evidently an alteration product of the limestone. It penetrates the latter irregularly and works inward along the laminæ from the surfaces exposed to attack.

Chemical analyses of the limestone and of the sooty powder are given in the following table:

Analysis of limestone and its alteration product.

[W. F. Hillebrand, analyst.]

Constituent.	I.	II.	III.
CaO	39.15	1.06	2.58
MgO	2.29	14.21	.97
CO_2	a 30.86	.47	....
H_2O at 110° C	.51	7.33	22.81
H_2O above 110° C	.66	a 8.88	
SiO_2	23.51	29.29	15.25
TiO_2	.06	.27	....
ZrO_2	None.	....	....
Al_2O_3	b 1.56	12.56	b 5.73
Fe_2O_3	.30	d 5.36	13.42
FeO	c .56		
MnO	e .54	MnO_2 13.27	MnO_2 33.77
ZnO	Faint tr.?	1.65	4.75
CuO	Faint tr.?	.40	f .72
PbO_2	....	5.21	....
BaO	Faint tr.	Faint tr.?	....
SrO	None.	....	....
Na_2O, K_2O	(?)	.20	....
Li_2O	....	Strong tr.	....
P_2O_5	Tr.	.14	Tr.
SO_3	....	Tr.	....
Total	100.00	100.00	100.00

a By difference.
b Trace of P_2O_5.
c 0.16 as carbonate.
d As Fe_2O_3.
e As carbonate.
f With CO_2, alkalies, etc.

I. Limestone. Forest-Payroll mine.
II. Alteration product or residue of above.
III. Oxidized material of Nellie Bly vein.

From the analysis in Column I, it appears that the limestone consists of about 70 per cent of calcium carbonate, with 30 per cent of siliceous and other impurities. The analysis in Column II shows that the alteration has consisted in the almost complete removal of the calcium carbonate and a strong hydration of the remaining constituents. The resultant product appears to be very largely residual in character, although probably modified by subsequently introduced material. In the absence of knowledge as to the mass relationship, or concerning the constancy of any one or more constituents, before and after the alteration, no quantitative comparison of the analyses is possible. The analysis in Column III is introduced for the sake of comparing the somewhat similar product resulting from the alteration of a calcitic vein.

The ore of the upper blanket consists mainly of galena in various stages of alteration to cerussite and anglesite. It occurs in small bodies at the intersection of the blanket by northwesterly fissures. It is not known to occur as a direct replacement of the limestone.

South Park blanket.—The South Park mine, at the northwest base of Newman Hill, was unfortunately not accessible in 1900. The ore is reported to have occurred partly in a blanket, in dark shales. If this is true, this blanket is the lowest known in Newman Hill, and occurs below the great sheet of monzonite-porphyry, while all the others lie above it.

C. H. C. blanket.—In C. H. C. Hill there is apparently one extensive blanket which has been exploited in the Princeton, C. H. C., Wellington, Logan, and Pigeon mines. All of the blanket thus far explored lies in a great landslide, and is consequently much broken and disturbed. This fact, coupled with the caving in of most of the old workings, makes it impossible to be quite sure that the principal blanket worked in the above-named mines is continuous and identical throughout. It certainly presents a more varied character, and is less open to simple explanation than those thus far described. It is thought to lie between beds of the upper division of the Hermosa, but this is by no means certain.

The blanket is usually 5 feet or less in thickness, and rests in some places upon sandstone, and in others upon limestone. It is overlain by sandstone or shale. It is most commonly composed of limonite, sometimes as a fairly firm, cavernous mass, but often as a loose, yellow, earthy material, which falls to powder between the fingers. In certain portions of the blanket the limonite passes into masses of crumbling iron pyrite, and it was undoubtedly formed by the oxidation of this mineral. The ore, when present, occurs in the lower part of the blanket, and is almost without exception completely oxidized. In the Princeton mine, the only place where any workable ore could be seen in 1900, it occurred in a soft, banded stratum, in which layers of an ocherous yellow powder containing a considerable proportion of silver, alternated with bands of impure pulverulent sulphate of lead, and streaks of a white material which proved on chemical analysis to consist of about 83 per cent of silica, 5 per cent of water, and 9 per cent of lead sulphate. The silica is probably in the opaline form. A little partly oxidized galena was seen in the southeastern part of the Logan mine, but its occurrence is apparently rare.

The main blanket of C. H. C. Hill is associated with considerable alteration of the rocks between which it lies. These changes are perhaps best studied in the Logan mine. The limestone which usually underlies the blanket has been largely attacked and removed by chemical processes. As a result its upper surface is most uneven. The process of removal is still in progress and the limestone is usually separated from the overlying blanket by a crust, an inch or more in thickness, composed chiefly of earthy gypsum (fig. 71, p. 392). What was supposed in the mine to be a thicker portion of the same crust of alteration proved on chemical examination to be halloysite, an amorphous, hydrous silicate of alumina, as shown by the following analysis, in which no other constituents than those enumerated were looked for:

Analysis of halloysite from the Logan mine.

[W. F. Hillebrand, analyst.]

Constituent.	Per cent
SiO_2	38.65
Al_2O_3	33.27
Fe_2O_3	.22
H_2O at 110° C	13.70
H_2O above 110° C	14.34
Total	100.18

The gypsum is evidently formed directly from the limestone by the action of solutions containing iron sulphate, derived from the oxidation of pyrite. This is just the process that has been suggested to account for the massive bed of gypsum in Newman Hill. But whereas there are no extensive bodies of oxidized ore in the Newman Hill mines, the enormous bodies of oxidized and oxidizing pyrite in C. H. C. Hill have produced only a thin, earthy crust of gypsum, which is probably now dissolving as fast as it forms.

A chemical analysis of the limestone underlying the C. H. C. blanket in the Logan mine is given below. It is an ordinary compact gray limestone, not unlike the so-called "short lime" of Newman Hill. The sample for analysis was taken close to the gypsum crust, the line between altered and unaltered limestone being sharply defined.

Analysis of limestone from Logan mine.

[W. F. Hillebrand, analyst.]

Constituent.	Per cent.
CaO	a55.10
CO_2	b43.39
SiO_2	.80
TiO_2	Trace.
Al_2O_3	.04
Fe_2O_3	.07
FeO	c.10
MnO	c.13
CuO	c.03
ZnO	c.09
MgO	c.25
BaO	None.
SrO	None.
H_2O at 110° C.	Not det.
H_2O above 110° C.	
P_2O_5	A little.
S	dTrace.
Total	100.00

a 0.03 not carbonate.
b By difference.
c As carbonate.
d As pyrite.

The analysis shows that the limestone is notably pure, containing very little silica or alumina. It is of interest to find that it contains appreciable amounts of manganese, copper, and zinc. The formation of halloysite in the neighborhood of the limestone must, in the light of the foregoing analysis, require the addition of alumina and silica from outside sources.

The sandstone, unlike the limestone, is not directly soluble or convertible into soluble substances. Although in surface exposures it is greenish in color, throughout the C. H. C. Hill mines it is prevailingly nearly white. Under the microscope it is seen to be composed chiefly of quartz and sericite, the latter mineral being probably derived in great part from former fragments of feldspar. This sandstone is usually hard and firm, but within a distance of a few feet above or below the blanket it is decomposed to a soft, white mass, containing small scattered flakes of sericite mica, and apparently preserving much of the granular structure of the sandstone. Examined in powder under the microscope, this material is found to consist of a micaceous mineral in exceedingly minute scales, probably sericite, and numerous crystalline grains of peculiar form. These are short, stout spindles, with rough surfaces, such as might be produced by the corrosion of minute, doubly terminated crystals of quartz. These spindles are usually less than 0.1 mm. in length. Their optical behavior, so far as can be determined in such small bodies, is that of quartz, and their hardness is at least 7 of Moh's scale. None of the original clastic quartz grains were detected in the altered material. Analyses of the altered and comparatively unaltered sandstone are given in the following table. The samples were taken only a few inches apart, but the two facies grade into each other:

Analyses of sandstone and its alteration product from the Logan mine.

[W. F. Hillebrand, analyst.]

Constituent.	I.	II.
SiO_2	83.95	62.88
Al_2O_3	*a* 8.92	*a* 21.38
Fe_2O_3	.48	*b* 1.09
FeO	.13	
MnO		Very little.
Ag	.04	None or tr.
Pb	Tr.	.34
Cu	Tr.	
MgO	.97	2.00
CaO	.12	.40
Na_2O	.06	.07
K_2O	3.09	6.59
H_2O at 110° C	*c* 1.90	*c* 5.49
H_2O above 110° C		
CO_2	None.	
P_2O_5	None.	
SO_3		.53
Total	99.66	100.77

a With some TiO_2. *b* As Fe_2O_3. *c* By ignition.

I. Sandstone.
II. Alteration product of above from same locality.

These two analyses, as they stand, constitute a comparison by unit weights. Such a comparison, however, is usually of little value in throwing light upon metasomatic changes, inasmuch as the latter nearly always involve change in specific gravity or in volume. Inspection of the analyses shows that if the percentages in Column II be divided by 2, the figures so obtained will indicate the preservation of a rough constancy in alumina, iron oxides, magnesia, lime, and potash throughout the alteration of the rock. This can hardly be a mere coincidence.

It at least indicates that the metamorphism has consisted chiefly in the removal of more than one-third of the silica of the original sandstone, the residual accumulation of the sericite, and diminution in volume. Partial mineralogical compositions may be very roughly calculated for the unaltered and altered sandstone as follows:

Sandstone.	Per cent.	*Alteration product.*	Per cent.
Quartz	73	Quartz	38
Sericite	24	Sericite	56
Other minerals	3	Limonite, anglesite, and some hydrous magnesium mineral	6
Total	100	Total	100

The occurrence of 0.04 per cent of silver in the apparently little altered sandstone is a wholly unexpected feature brought out by the analysis in Column I. This percentage is equivalent to 11.5 ounces per ton, and indicates that a large amount of silver is probably disseminated through the country rock of C. H. C. Hill in the neighborhood of the blankets.

The great extent to which oxidation has been active in the C. H. C. blanket renders the interpretation of the foregoing alterations difficult. Both the limestone and the sandstone show changes attributable to acid waters. The conditions for supplying surface waters with the necessary chemical activity are present wherever large bodies of pyrite are undergoing oxidation. It is very probable that the alterations just described are comparatively recent phenomena which have obscured whatever metamorphism accompanied the original deposition of the pyrite.

As might be expected from its position in a great landslide mass, the C. H. C. blanket, as well as the rocks which inclose it, shows much disturbance. Small step-faults, letting the blanket down by successive drops to the southwest, are said to have been very common in the old stopes, while irregular fracturing is everywhere conspicuous.

In addition to the main blanket of C. H. C. Hill, several blanket-like masses of pyrite occur at other horizons in the stratigraphic series. Three such bodies of crumbling pyrite, inclosed in shales, and aggregating over 50 feet in thickness, were passed through in the Crebec shaft before the main ore blanket was reached. Although nearer the surface than the latter, these pyritic bodies show almost no oxidation, and are too low in grade to be worked under present conditions. Similar, but smaller, bodies were noted in the Logan mine, extending into beds of shale on the southwest side of the Pigeon lode. In the Pigeon mine a small local blanket was found below the main "contact," and carried a little ore on the southwest side of a northwesterly fissure.

Some ocherous yellow, so-called "carbonate ore," collected from this blanket, proved on chemical examination to be composed mainly of the hydrous sulphate of iron and potassium, known as jarosite. A chemical analysis of this material is given below.

Analysis of impure jarosite from Pigeon mine.

[W. F. Hillebrand, analyst.]

Constituent	Per cent.
SiO_2 (mostly quartz)	7.35
Al_2O_3	1.00
Fe_2O_3	43.81
MgO	Trace.
CaO	.06
Na_2O	.08
K_2O	7.44
H_2O	11.64
P_2O_5	.33
SO_3	28.20
Total	99.91

The particular sample analyzed can not be termed an ore. It was undoubtedly derived from the oxidation of iron pyrite, but is interesting as showing that considerable potash was probably present in some of the oxidizing solutions.

Still other relatively unimportant blankets, probably distinct from any of those described, are found in the Lily D. workings, on the lower slopes of C. H. C. Hill.

Taking them as a whole, the blankets of C. H. C. Hill present a striking contrast to that of the Enterprise mine. The constant shale breccia, passing below into the silty mixture of dolomite and celestite, which is so characteristic of the latter deposit, is absent in C. H. C. Hill, where the blankets appear to have been originally sheet-like or lenticular bodies, consisting chiefly of pyrite. The Enterprise "contact" is practically unoxidized, while the main blanket of C. H. C. Hill is almost wholly transformed to secondary products, and its earlier history thereby obscured. Without such oxidation and secondary enrichment, however, the ore would probably have been too poor to extract.

A. B. G. blanket.—On the west side of the Dolores River a small blanket occurs in the A. B. G., a prospect at Burns. This is composed of partly oxidized, crumbling pyrite, about a foot in thickness, lying between the beds of the Lower Hermosa, on the southwest side of the over the northeasterly lodes, always "made" to one side of the northwesterly fissures, usually on the down-faulted side. The miners in general corroborate this statement, but there was no opportunity for confirming it at the time of visit.

With possibly one or two exceptions, which, however, are no longer open tó examination, the lodes of Newman Hill do not extend above the blanket. The overlying rocks are much fractured and contain some unimportant veins, which may have been formed at the same time as the lodes beneath the blanket. But there is no good reason to suppose that they were ever continuous with the latter. The upward limitation of the lodes by the "contact" is a natural consequence of the slight faulting which accompanied the opening of their fissures and the yielding fissile character of the beds in which the "contact" lies. If the lodes continued in full strength up to the blanket and were there abruptly cut off it would be natural to suppose that they once extended to the surface and that their upper portions have been displaced by faulting. But not only do they practically die out, as lodes, before the blanket is reached, but the relations of the blanket ore to the lodes, of the blanket to the gypsum, and the nature of the blanket itself all support the view that the latter has not been a plane of extensive or general faulting.

In the Union-Carbonate and Forest-Payroll mines the blanket ore is connected with northwesterly fissures which apparently pass through the blankets without interruption. Whether or no the fissures are slightly faulted as they traverse the blankets could not be satisfactorily determined with the available exposures. The prevalent oxidation in these mines and the recent slipping along the lodes, as attested by the presence of gouge, tend to obscure the original relationship between lode and blanket.

In C. H. C. Hill the mineralization of the main blanket and of most of the smaller ones has plainly emanated from the great Pigeon–Blackhawk lode. Here, too, subsequent movement and oxidation have obscured the details of original connection. In this case the blanket is without much doubt considerably faulted by this lode, but it is impossible to say how much of the faulting took place before and how much after mineralization. All the ore so far extracted from the blankets of C. H. C. Hill has occurred on the southwest side of the Pigeon–Blackhawk lode. On the northeast side of the lode the blanket horizon was probably dropped by the original fault. But how far its position has since been changed by later movement, including landsliding, is not known.

The blanket ore of the C. V. G. mine at Burns is evidently connected with the northwesterly lode lying northeast of it, but the connection is not exposed.

In the Sambo mine the blanket is continuous with a lode which faults the Lower Hermosa beds to the extent of at least 4 feet. As shown in fig. 64, page 366, blanket and lode are directly connected. The ore occurs on the southwest side of the lode and extends into the blanket for a maximum distance of about 30 feet.

REPLACEMENTS IN LIMESTONE.

The principal examples of this form of ore deposition are found in the Blackhawk, Iron, and probably, also, the Puzzle mines. The Atlantic Cable and other prospects in the Ouray limestone north of Rico must also be placed in the same category.

In the Blackhawk the replacement ore bodies occur on the northeast side of a lode belonging to the Blackhawk fault zone. They have irregularly replaced a bed of massive limestone belonging near the top of the Middle Hermosa and dipping away from the lode to the northeast at an angle of about 25°. They attain a thickness of more than 15 feet and extend to a maximum distance of 50 or 60 feet from the lode. These bodies are composed in great part of massive pyrite of no present value, in which lie irregular bodies of workable ore. The best of this consists of fine-grained galena, chalcopyrite, and pyrite in a gangue of fluorite. Such ore grades toward its periphery into lower grade ore, large quantities of which are still standing in the mine. This is composed of massive compact sphalerite and galena, with a little chalcopyrite, and practically no gangue. This ore in turn passes into enormous masses of nearly pure worthless pyrite or is directly inclosed in limestone.

As a rule, there is no sharp boundary between limestone and ore. The latter sometimes penetrates the white granular limestone in small bunches, but more often the limestone next the ore is changed to jasperoid.

For a fuller characterization of this deposit the reader is referred to the detailed description of the Blackhawk mine, on pages 368 to 373. The deposit is an ordinary case of simple metasomatic replacement which has extended outward from a lode fissure.

Similar in character is the occurrence of the ore in the Iron mine. Here Middle Hermosa limestones are partly replaced by ore on both sides of a lode which does not noticeably fault the beds. In the Iron mine the workable ore extends less than 12 feet from the lode, except in some cases where replacement has worked out along minor fissures in the limestone. The ore is usually massive, consisting chiefly of pyrite and chalcopyrite, with more or less calcite and quartz as gangue. It is of low grade. The ore has replaced the limestone directly, with little or no formation of jasperoid.

The mode of occurrence of the ore in the Puzzle mine is at present not directly determinable. It appears, however, to have been an irregular replacement of limestone by a siliceous ore containing argentite or other rich silver minerals. The ore occurred in a landslide block, and it is not known in what manner the replacement was brought about—whether the solutions emanated directly from a lode, or whether they found access, by various channels, to a brecciated zone or bedding fault immediately above the limestone.

In the Atlantic Cable and neighboring prospects, the Ouray limestone has been most irregularly replaced by more or less isolated bunches of ore of various sizes. The deposition of this ore was closely connected with a metamorphism of the limestone giving rise to chlorite, epidote, garnet, and wollastonite, as described on page 395. The ore consists chiefly of sphalerite, chalcopyrite, and galena, associated with much specularite. It is not visibly connected with any parent lode or fissure.

STOCKS

The only examples of this form of deposit known in the Rico district are in the Johnny Bull and Gold Anchor mines, at the head of Horse Creek. These, however, are individually of small importance and are but poor representatives of a type which finds much better exemplification in the stocks of the Red Mountain district in the San Juan Mountains.

The Johnny Bull stock has a diameter of 10 or 15 feet, and a depth of about 120 feet. It was inclosed in fine-grained sandstone of the Dolores formation, which is here cut by several dikes and irregular intrusions of porphyry. The ore, consisting of enargite, pyrite, free gold, and probably other minerals, was deposited largely by replacement of the sandstone, which is silicified and impregnated with pyrite in the vicinity of the former ore body.

A similar smaller stock, consisting chiefly of pyrite, occurs at a lower level in the Gold Anchor mine, nearly under the Johnny Bull.

GENESIS OF THE ORE DEPOSITS.

If the preceding account of the ore deposits of the Rico district clearly and truthfully sketches their essential features, the statement that they are genetically connected with the present geological structure of the region requires no further demonstration. But it remains to investigate this general and fundamental connection more closely, in order to properly discriminate and distribute the various effects traceable to one common source—the geological revolution through which beds, once nearly horizontal, have been elevated into a fissured dome, and subsequently carved by erosion into the topographic forms known as the Rico Mountains.

The vertical extent of the original Rico uplift is estimated by Cross and Spencer[1] at about 4,500 feet. A minor part of the elevation, at least 800 feet, is connected with the intrusion of sheets of porphyry between the beds of the sedimentary series. But the major part of the uplift was subsequent to these intrusions, and was associated with profound faulting, showing "the action at this center of a powerful vertical upthrust which is not demonstrably connected with igneous intrusion."[2]

Fuller discussion of the origin of the uplift is deferred by these writers until the movements of the San Juan region as a whole shall have been further studied.

That the ore deposition is chiefly connected with the later phases of uplift is shown by the fact that the intrusive porphyries are themselves traversed by lodes, and are invariably mineralized when occurring in contact with ore bodies. But it is probable that some of the conditions favorable to the occurrence of ore bodies were initiated during, or even *before*, the earlier stages *of the* uplift. This is particularly true of the blankets, which Cross and Spencer have discussed to some extent under the heading of "Bedding faults;" that is, dislocations which follow planes of stratification. It will be well, first, to consider briefly the immediate causes which led to the formation of individual blankets, and, afterwards, to determine the relation of these direct and local manifestations of activity to the general geological history of the region.

ORIGIN OF THE BLANKETS.

Study of the Enterprise blanket has confirmed the general suggestion tentatively thrown out by Spencer, that it is due essentially to the removal by solution of a massive bed of gypsum which may have been from 15 to 30 feet in thickness. As the gypsum has not dissolved at an equal rate throughout, and has been largely attacked from below, with the consequent formation of caverns, the overlying beds must have subsided unevenly as the gypsum was removed, and were probably often let down abruptly by the enlargement and final collapse of caverns of solution in the under side of the bed. Nearly all stages of the process may yet be seen in the Newman Hill mines, from the usual "contact," with no remaining gypsum, to a thick bed of the latter, showing (at least on its under surface, which alone is visible) places where solution has not yet been active. This irregular subsidence, proceeding at different rates at different times, throughout the area now occupied by the blanket, is amply sufficient to account for the brecciation of the overlying shale and for the generally shattered character of the rock up to the base of the wash covering Newman

[1] Loc. cit., p. 22.

[2] Cross and Spencer, loc. cit., p. 112.

Hill. Indeed, the results of this subsidence find partial expression in the present topographic form of Newman Hill.

That more or less movement has taken place in the mass of shale breccia precipitated upon the soft, pulverulent residue of the gypsum is well shown by the occurrence within it of irregular seams of gouge. Such movement is probably still in progress, but it is chiefly local in character, due to varying adjustments, under gravitative stress, within the plastic mass. It can not be ascertained that any general faulting has taken place along this soft and structurally weak zone. Such faulting, if it occurred, has certainly not been extensive, and its assumption is not necessary to account for the brecciation. The lack of general faulting along the zone of such apparent weakness is probably to be accounted for by the local character of the blanket, its warped form, and the occurrence of solid masses of undissolved gypsum, all of which would tend to prevent general slipping.

As the gypsum was deposited in Carboniferous time, its solution may have begun at an early date; but it was probably much accelerated, if not initiated, by the original doming of the rocks coincident with the intrusion of sheets of porphyry between the beds. The later fracturing, which was associated with the final stage of uplift, must have still further hastened the process of removal by allowing to underground waters, heated by the intruded masses of igneous rock, a more active circulation.

The upper blanket of the Forest-Payroll mine is somewhat analogous in origin to that of the Enterprise. It is due in great measure to the local solution of a bed of limestone, and the consequent letting down of the overlying shales. In this case the residue of the limestone is a sooty material containing much oxide of manganese. Owing to the prevalent oxidation in this mine, it is impossible to determine whether the ore was originally deposited in the limestone before its solution. Apparently it was not.

Of still different origin are certain of the lesser "contacts" studied in the Union-Carbonate mine. In these the process has been purely chemical. Certain beds of shale have been wholly or practically altered to a soft, ferruginous, clay-like mass containing some oxidized ore. The fact that some of these soft zones are cut by dikes or porphyry (intruded prior to the alteration) which have not been fractured or displaced shows that their formation is unconnected with faulting along planes of bedding.

The genesis of the main blanket of C. H. C. Hill is not perfectly clear, owing to later oxidation and disturbance. It was evidently originally a large body of low-grade pyrite which has undergone oxidation and a concentration of its valuable constituents. This pyrite apparently occurred in large part as a metasomatic replacement of shale, limestone, and sandstone. But whether this replacement was preceded by brecciation is not known.

There are, however, a number of blankets in the district, such as those found in the Sambo, Great Western, Bancroft, Silver Swan, Little Maggie, and New Year mines, and probably the main "contact" of the Union-Carbonate mine, which seem to owe their existence chiefly to bedding faults. It can not be positively affirmed, however, that all of the blankets named are purely fault breccias. It is quite possible that some of them may have been initiated by the solution of gypsum, as in Newman Hill, and the traces of such genesis have been obliterated by subsequent movement.

The stratigraphic conditions under which, in this region, such brecciation has taken place are fairly constant. The fissile black shales of the Lower Hermosa are the rocks usually involved, not only by reason of their intrinsic weakness, but on account of their present distribution with reference to the center of orographic movement. Such shales are particularly susceptible to brecciation near their contact with some more rigid member of the lithological series, such as a sheet of porphyry, or massive beds of sandstone or limestone. When the bed of shale is relatively thin, and is inclosed between the massive strata, it is often entirely reduced to breccia. That the actual relative movement of the stronger beds need not be very great to produce brecciation in the shales between them is well illustrated in the Rico-Aspen mine, near the Silver Glance shaft. Some of the shales below the blanket limestone, lying between thin beds of sandstone, are here locally folded and crumbled to the verge of brecciation, while the sandstone above and below them are undisturbed, and the crumpling itself has no great horizontal extent. Similar incipient "contacts" in various stages of development were noted in the Little Maggie and other mines, often having but small horizontal extent, and plainly formed by only slight movements along planes of bedding.

A part of the necessary movement probably took place at the time of the initial doming of the beds by laccolithic porphyry intrusions. But the greater part, and obviously that which produced brecciation along the contacts between porphyry and shale, must have been effected when the final elevation was given to the dome by upthrust and faulting, and the rocks accommodated themselves to their new positions by slips along the bedding planes.

ORIGIN OF THE LODE FISSURES.

It is to this general period of later orogenic movement that the present fissure systems of the region belong. Such earlier fractures as may have resulted from the first relatively gentle doming were probably superficial in character over the central region of the dome and have been largely removed by erosion. The more deep-seated fissures which presumably opened beneath the flanks of the uplift were in all likelihood filled with dikes at the period of laccolithic intrusion. It is to the later fractures, which traversed the solidified masses of monzonite-porphyry, and which served as channels through which ore-bearing solutions could penetrate to the blankets, that the ore deposits are really due.

That the fissuring did not all take place at one time is shown by the fact that many of the lodes, particularly northwesterly lodes, show evidence of repeated opening; that the northwesterly fissures of Newman Hill, although probably initiated at the same time as the northeasterly fissures, subsequently faulted the former in several instances; and that the fissures of the Phenix and Iron veins are apparently younger than the Nellie Bly fault. In fact, it is only necessary to study such lodes as the Aztec or Calumet, or the northwesterly lodes of Newman Hill, to see that movement along existing nearly vertical planes of weakness has continued to a very recent date.

One of the striking generalizations afforded by the study of the district has been the lack of coincidence between those fault fissures of such extent as to appear as "structural faults" and the lode fissures. Cross and Spencer, in their remarkably successful elucidation of a most difficult field, have to some extent obscured this distinction, through their procedure, not unnatural in such a region, of identifying a fault required by their interpretation of the geological structure, with the nearest lode of like trend exposed on the ground. An unfortunate result of their terminology is an apparent confusion of the Nellie Bly fault with the Nellie Bly vein, and, in consequence, of the latter vein with the Aztec lode.[1] Less important is the supposed identity of the Last Chance fault with the Last Chance lode, inasmuch as lode and fault are in this case certainly very closely related. That some faulting has taken place along lodes, both before and after their filling, is of course undeniable. But the great fault fissures of the district, numerous as they are, apparently nowhere carry workable bodies of ore, and are certainly only to a minor extent coincident with veins. The northeasterly veins of Newman Hill, and less certainly the northwesterly veins of Nigger Baby Hill, show that the favorable channels for ore deposition were not the great fault fissures which gave the district its final structure, but were clean, open fractures of but slight tangential displacement. Such fissures show no clear evidence of horizontal compressive stress. They are, so far as faulting has taken place, in the main, normal faults. It is believed, although not entirely demonstrable, that they represent the relatively slight readjustments necessary to restore the rocks to gravitative equilibrium after the greater faults had determined the main structures of the region.

[1] Cross and Spencer, loc. cit., p. 119.

PAY SHOOTS.

The superficial character thus far shown by the pay shoots is one of the most interesting phenomena of the Rico district, and vitally concerns the permanence of its mining industry. As pointed out in the preceding sections, only a relatively small number of the lodes have been themselves productive, and those to a comparatively slight depth. In the case of the Nigger Baby Hill, Little Maggie, and Alleghany veins, the most important falling off in value takes place at the passage of oxidized into unoxidized vein matter. These veins thus owe their workable portions to a process enrichment which is of common occurrence elsewhere, is wholly secondary, and is well understood in its general features. Below this zone of oxidation the veins have not been successfully worked, and it is not certainly known whether the value of the primary ore suffers a still further diminution with increasing depth. This, however, seems probable.

The rather abrupt falling off in value of the northeasterly veins of Newman Hill at a depth of less than 200 feet below the blanket is not so readily accounted for. It will be recalled that both the northeasterly and northwesterly lodes are capped by pay shoots in the Enterprise blanket, those over the northwesterly lodes being usually the larger and richer bodies. As far as can be determined, the blanket ore over the northeasterly veins did not differ mineralogically from that over the northwesterly lodes. Furthermore, at a depth below the blanket greater than 200 feet the contents of the two sets of lodes are mineralogically identical. It thus appears that the mineralogical difference between the northeasterly and northwesterly lodes, which is so striking a feature in certain of the mine workings, is not, after all, so great as might at first be supposed from a comparison confined to one level. The contrast is one brought about mainly by the difference in depth to which the ore extended in each case.

Various hypotheses have suggested themselves in explanation of this phenomenon. Difference in the country rock can not be appealed to, for both sets of lodes traverse the same beds. For the same reason, differences in pressure and temperature can scarcely have been important factors. If, however, the northwesterly lodes are in the main later than the northeasterly, it is inevitable, from what is known of its origin, that some change in the overlying blanket must have taken place in the interval. It is possible that this change may have been of a character to influence ore deposition.

It has been thought possible that at the time the northwesterly lodes were being formed the gypsum may have been only in small part dissolved. In such case the blanket ore may have been originally deposited chiefly as a replacement of gypsum, a process which is known to have operated in some portions of the blanket zone. The ore-bearing solutions, checked by the gypsum overlying the lodes, and not finding in the slow process of metasomatic replacement sufficient opportunity for the deposition of their metalliferous contents, may have encountered in the upper portions of the fissures conditions favorable to the deposition of ore. One such general condition of ore deposition is believed to be sluggishness of circulatory motion in the ore-bearing solutions.

If mineralization through northwesterly fissures was of later date, it is conceivable that the more complete removal of the gypsum may have given all of the ore an opportunity for deposition in the unconsolidated blanket material.

If the foregoing hypothesis is correct, some structural evidence for it might be expected in the ore of the northeasterly pay shoots of the blanket. Unfortunately, however, all of the known ore has been mined out.

It has been previously pointed out that some grounds exist for supposing that the northwesterly fissures, while initiated at substantially the same time as the northeasterly fissures, did not gape open until a later date, and that such opening was gradual and intermittent. This suggests, as a second hypothesis, that the blanket ore may have all been formed at the same time, before the full opening of the northwesterly fractures, and that the nonoccurrence of ore in the northwesterly fissures is due to their contracted openings at the time of ore deposition.

Of the two hypotheses advanced, the former is regarded as more probable. But it is admittedly not much more than a suggestion, of which no demonstration can be made under existing conditions. But whichever one is accepted requires to be supplemented by further considerations relating to the chemical causes of precipitation before it can be regarded as complete.

Rickard[1] has advanced the view that the precipitation of the ore was effected by the "graphite" in the shales. In spite of the experiments recorded by him, in which silver and gold were artificially precipitated from solution by fragments of this shale, such direct and simple precipitation has evidently not taken place in nature. The ore, as has been shown, is not particularly associated with the shales, either in the lodes or in the blanket. In the former it is more commonly found between walls of sandstone, and in the latter it occurs mainly as a replacement of the pulverulent residue of the gypsum.

The view that those ore bodies showing a marked decrease in valuable sulphides with depth, and passing finally into practically barren pyrite, are due to the action of both ascending and descending solutions has come to be widely accepted, largely through its forcible presentation

[1] Loc. cit., p. 977.

by Van Hise.[1] The Newman Hill pay shoots appear to constitute striking examples of ore bodies due to the mingling of solutions. That the purely ascending solutions rising through the fissures of this region have normally deposited only low-grade pyritic ores is abundantly exemplified throughout the district. But such solutions ascending in the fissures under the Enterprise blanket not only found their upward progress barred by the impervious shales above, but entered a markedly porous, unconsolidated zone, traversed by laterally moving solutions which must then, as now, have carried considerable calcium sulphate in solution. Too little can be learned of the chemical nature of the fissure solutions to determine whether the calcium sulphate acted as the precipitant. But that the precipitation was due, at least in part, to mingling solutions and not entirely to metasomatic replacement within the blanket is indicated by the fact that the ores extend below the latter for over 100 feet in the northeasterly lodes. It is thus seen that the depth to which deposition of pay ore extended in the lodes may have been determined by the equilibrium between the ascending solutions in the lode fissures and the laterally descending solutions in the blanket. Evidently if the lode fissures were small, and filled with solutions moving upward under considerable head, all the ore would be deposited in the blanket.

Turning now to the other known blankets in the district, we find that none of them have contained such large or rich pay shoots as the Enterprise blanket. With the exception of an oxidized lode in the Union-Carbonate mine, the fissures through which the mineralization of these blankets has taken place are barren, or contain only a little low-grade ore. It is evident that the conditions for ore deposition in the Enterprise blanket were unusually favorable, and were determined in varying degree by the following peculiarities, which are not found associated together in any other blanket known in the district: (1) The underlying blanket limestone; (2) the gypsum and its pulverulent residue; (3) the overlying, nearly impervious, bed of black shale; and (4) the upward termination of the lodes at the blanket horizon. But although no one of the other blankets possesses all these advantageous attributes, yet they illustrate the general fact that in this region, ignoring for the present replacement deposits in limestone, large bodies of workable sulphide ores occur only where the solutions in the lode fissures have had opportunity to mingle with laterally moving solutions in a blanket. The extent and richness of the deposit depend largely upon the number of favorable conditions enumerated above which are present in any one case.

A similar statement may be made with regard to replacement deposits in limestone. Lode fissures which ordinarily carry no pay ore are

[1] Some principles controlling the deposition of ores: Trans. Am. Inst. Min. Eng., Vol. XXX, 1900, pp. 27–176.

frequently connected with bodies of workable ore in limestone, as in the Blackhawk and Iron mines. In such cases the concentration, which has enabled solutions ordinarily capable of depositing only low-grade pyritic ore to form relatively rich sulphide masses, has been effected not so clearly by mingling of solutions as by the process, probably in large part selective, of metasomatic displacement.

SOURCE OF THE ORES.

The ores of the Rico district were extracted from the rocks by aqueous solutions and concentrated under the conditions already described. In this, as in many other regions, stratigraphic disturbance, igneous intrusion, and ore deposition have been genetically connected. The ore-bearing solutions undoubtedly owe much of their efficiency in gathering, transporting, and depositing the ore constituents to heat derived from igneous activity. That some of this heat still remains is indicated by the thermal character of the water issuing from the west base of Nigger Baby Hill. It is possible, although not clearly indicated, that pneumatolytic emanations (i. e., gaseous products given off at high temperature) from the cooling masses of intrusive monzonite-porphyry may have increased the chemical activity of the originally meteoric water. But the known porphyry masses had certainly solidified and probably lost much of their initial heat before the ores were deposited. Moreover, had pneumatolysis been an efficient factor in ore deposition, we should expect to find the ores unmistakably related, both in genesis and position, to the porphyry masses. No such close relationship is apparent, unless the exceptional ore bodies in the Atlantic Cable and neighboring claims may be considered as indicating it.

The actual chemical character of these solutions is not readily determinable. Their action upon the sedimentary rocks which usually form the walls of the fissures is, with a few exceptions, inconspicuous and often obscured by secondary alteration. The presence of abundant calcite in the lodes of Nigger Baby Hill and of rhodochrosite in the upper part of the northeasterly lodes of Newman Hill indicates that the solutions contained carbonates, possibly alkaline carbonates. But the strong silicification of porphyry alongside of the Mohawk and Marriage Stake fissures points rather to the action of acid waters. It is possible that the waters ascending in the lode fissures were acid in character, but were modified by mingling with descending waters, the change from acid waters depositing quartz and pyrite to carbonate waters depositing calcite and rhodochrosite corresponding in general to the deposition of pay ore.

Equally impossible of definite answer is the question of the particular rocks and the precise depth from which the ores were derived, but it is believed that all of the rocks, particularly from the top of the

Rico formation down, have contributed some metalliferous constituents to the ore bodies, not by the narrowly confined, academic process known as "lateral secretion," but by the concentration, in favorable localities, of materials widely drawn from the rocks of the disturbed region, and often reaching the point of their final deposition after a roundabout journey to depths far below any ever likely to be reached by mining operations.

That small amounts of the heavy metals are at present widely distributed in the rocks of the Rico region, even when the latter show no visible signs of mineralization subsequent to their deposition, is shown by several of the chemical analyses made for this report. Thus, the limestone from the Forest-Payroll mine affords faint traces of zinc and copper. Limestone from the Logan mine contains 0.03 per cent of copper oxide and 0.09 per cent of zinc oxide, while sandstone from the same mine yields traces of lead and copper and 0.04 per cent of silver. Even the massive gypsum from the Rico-Aspen mine shows a faint trace of some metal precipitated by hydrogen sulphide. All of the specimens analyzed, however, came from the vicinity of ore bodies, and the introduction of heavy metals in sufficient quantity to be recognized in an ordinary chemical analysis is probably connected with the formation of the neighboring ore bodies. There are, however, no known criteria for determining whether minute traces of heavy metals found in sedimentary rocks are original or have been subsequently introduced.

The formation of the ore of the Atlantic Cable and neighboring claims is evidently connected with intense contact metamorphism, as shown by the paragenesis of the ore minerals and their close association with garnet, wollastonite, vesuvianite, pyroxene, chlorite, and epidote. The cause of this metamorphism is not clear. It is probably traceable, however, to the intrusive mass of monzonite between Iron Draw and Aztec Gulch, or possibly to some igneous mass which has been removed by erosion.

GEOLOGICAL AGE OF THE ORE DEPOSITS.

The age of the ore deposits can not be determined from a study of the Rico district alone. They are plainly subsequent to the doming and faulting of the region, but no definite date is assigned to these structures by Cross and Spencer. A tentative conclusion, however, may be drawn from the similarity in character between the monzonite of the Rico district and that of the Telluride and Silverton regions. It may be assumed as probable that the monzonitic intrusions of the San Juan Mountains and Rico Mountains, only a few miles apart, are referable to the same general period of igneous activity. In the San Juan the monzonite stocks cut the Telluride conglomerate (Eocene?) and the overlying volcanic series. Their intrusion probably took place in late Tertiary time. This relation indicates that the ore deposits of Rico are roughly of the same age as those of the San Juan Mountains, probably late Tertiary and possibly extending into the Pleistocene.

VALUE OF THE ORES.

The great bulk of the ore produced in the Rico district has been shipped crude, or smelted in Rico without previous mechanical concentration. Consequently the ore handled has been of rather high grade. Ore worth about $20 a ton, such as was produced from the Union-Carbonate mine, is considered "low grade." The ore of the Enterprise and Rico-Aspen mines varied widely in value but was usually rich. Thus, during one year, the average of the Enterprise was 200 ounces of silver and 2 ounces of gold per ton. One carload from this mine (about 10 tons) was valued at $8,000. The general range, however, appears to have been gold, from 0.2 to 1 ounce; silver, from 100 to 200 ounces; lead, up to 10 per cent; and zinc up to 15 per cent. The ore from the Rico-Aspen and Newman mines has generally been of lower grade than that of the Enterprise.

Some of the oxidized ore from Nigger Baby Hill was rich in silver, but rarely carried over 0.2 ounce of gold per ton. In 1900 ore containing over 300 ounces of silver per ton was being shipped in occasional carloads. Ore from the Hope and Cross mine has sometimes yielded over 200 ounces of silver per ton in carload lots.

The ore of the Puzzle mine is reported to have been rich, but in general the replacement bodies in limestone, such as those of the Blackhawk and Iron mines, are of relatively low grade. That from the Blackhawk contained from 10 to 30 ounces and that from the Iron mine from 20 to 40 ounces of silver, with practically no gold.

An attempt was being made in 1900 to rework the dump of the Enterprise mine by concentration, but the mill erected for this purpose was not in successful operation at the time of visit.

CARBONIC ACID GAS.

Prospecting within the Rico district is often much hindered by the abundance of carbonic acid gas, which issues from nearly every fissure traversing the rocks in the central portion of the dome. It is particularly troublesome in shafts, which become entirely filled by it. It occurs in the Lexington, Mediterranean, and Syndicate tunnels to such an extent as to render them inaccessible unless artificially ventilated, and a stream of this heavy gas was noted issuing from a fissure in the Blackhawk mine. But it is in the immediate vicinity of Rico that the evolution of the gas is most abundant. On the west bank of the Dolores River, on the Riverside, Smuggler, and Shamrock claims, it issues in many places with a bubbling noise loud enough to attract the attention of the passer-by, and in such volume as to suffocate birds and small animals that venture too near, attracted by the water through which it escapes. About 300 feet upstream from the Piedmont bridge the water of the river is kept in a state of violent ebullition by the escape of gas, apparently from an east-west fissure. A similar copious discharge constantly agitates the water in the bottom of the so-called "gas shaft," a shallow prospect on the southwest slope of Nigger Baby Hill. As shown by bore-holes on the Atlantic Cable claim and in the Rico-Aspen mine, underground reservoirs of gas exist under considerable pressure. In fact there is scarcely an opening in the ground near Rico that does not fill up with gas, and not a stretch of the river between the mouths of Sulphur and Horse creeks where bubbles of carbon dioxide may not be seen rising through the water.

It is possible that the evolution of gas may be a final manifestation of volcanic activity, and that its source lies at great depth. This view is in harmony with the issue of thermal water near the base of Nigger Baby Hill and with the former solfataric action indicated by the alteration of the porphyry of Calico Peak.[1] But it is also probable that carbonic acid gas is being continually produced by chemical reactions at moderate depths, especially by the action of acid solutions on the limestone. Such a reaction is the transformation of limestone into gypsum through the agency of sulphate solutions, observed in C. H. C. Hill. It is also conceivable that replacement of limestone by sulphide ore is still going on, giving rise to carbon dioxide. But this is not very probable, as the known bodies of limestone have been found to extend to less than 200 feet in depth. Below them lies quartzite of supposed Devonian age, resting unconformably upon the Algonkian rocks.

LANDSLIDES.

For full descriptions of the extent and character of the landslides of the Rico district the reader is referred to the chapter on this subject by Mr. Cross[2] in the paper so frequently referred to in these pages. Mr. Cross believes that they were caused by earthquake shock.

They are of later date than the period of ore deposition, but have an important economic interest on account of the hindrance which they impose upon successful exploitation. This is well illustrated in the case of the Puzzle mine where a body of rich ore occurred in a landslide mass which has slipped down from Darling Ridge and buried the former channel of Horse Creek. All attempts to find the source of this block, and the continuation of the ore body, have failed. The difficulty of the problem is apparent upon referring to the geological map (Pl. XLI) where it is seen that the whole northern slope of

[1] Cross and Spencer, loc. cit., p. 93.

[2] Loc. cit., pp. 129-151.

Darling Ridge is covered with landslide material. The depth of this material is often several hundred feet, and rock in place can be reached only by tunneling. There is no means of knowing how far the Puzzle mass has slid. Even if the original source of the block is found after tedious and expensive prospecting it is by no means certain that there will be any ore there.

Similar difficulty is encountered in the landslide of C. H. C. Hill, which, as shown by the various mine workings, has a maximum thickness of several hundred feet. In this case also all of the ore thus far found has been in landslide material, and the main ore horizon has never been found in rocks in place. Even if discovered it is by no means certain that it would contain workable ore.

Similar conditions of obscurity obtain over a considerable area north of Horse Creek and on the southeast spur of Expectation Mountain. Prospecting undertaken in these areas without some realization of the nature of the disturbance which they have undergone is almost inevitably doomed to disappointment.

FUTURE OF THE DISTRICT.

No attempt to forecast the future of the Rico Mountains as a mining district can be fully assured of success. The following views are, at best, deductions from phenomena only imperfectly understood, and perhaps susceptible of different interpretation by others. Suggestions advanced after a few months' study of the region are not infallible, and should in all cases be considered in the full light of local knowledge and experience before being blindly followed.

From the description and discussion of the ore bodies, it appears that in the future, even more than in the past, the blanket and replacement deposits will prove of more importance than the lodes. It seems very doubtful whether, under the conditions of working likely to prevail for many years, the lodes can be extensively and profitably worked. The finding of small amounts of gold ore from time to time in the northwestern portion of the district leaves open the possibility that workable gold-bearing lodes may yet be opened up in this part of the area. But the prospects of extensive future development in this direction are not regarded as particularly bright.

As to the blankets, it is hardly probable that, in future, ore bodies will be found which will equal in richness and size those formerly mined in the Enterprise blanket. But the extent of this blanket is as yet imperfectly known. Followed under Dolores Mountain, it was found to grow smaller and to contain no ore. This portion was not accessible in 1900, but before exploration in this direction is abandoned it should be carefully determined whether the blanket, as far as prospected, still contains the pulverulent residue which testifies to the former presence of gypsum. If it does, then it would appear that there is still a fair probability of bodies of ore occurring to the east of those hitherto worked. On the south the blanket is, without much doubt, cut off, and, as Cross and Spencer estimate, has been dropped about 250 feet. The chances of finding bodies of ore in this downthrown portion of the blanket can be decided only by a knowledge of the ore bodies lying immediately north of the fault. If these became impoverished before the fault was reached, the probabilities are that the blanket south of Deadwood Gulch is not heavily mineralized. The general indications, drawn from mine maps and other sources, point to such impoverishment. But according to other accounts rich ore was found in the blanket up to the line of the fault.

The occurrence of the New Year blanket shows that there is at least one "contact" below that of the Enterprise, and probably others exist beneath the porphyry. They are of different character, however, from the Enterprise blanket. It is probable that they contain ore at their intersection by the lodes of the Enterprise and neighboring mines, but it is likely to be of lower grade than that hitherto worked.

On C. H. C. Hill the blanket-ore has thus far been found only on the southwest side of the Blackhawk-Pigeon lode. It is probable that the corresponding beds on the northeast side of this fault-fissure are also mineralized. They may not be oxidized, however, and in this case would be of low grade.

Considering, finally, the replacement deposits in limestone, we find that they have been only partially explored. As pointed out on page 372, the Blackhawk mine has exploited only one of several beds likely to contain ore. The Devonian limestone north of Rico, and extending eastward under the Hermosa beds, has been only superficially prospected, and no attempt has been made to determine whether it has been extensively mineralized by the Smelter and South Park fault fissures.[1] It must be said, however, that the outlook for finding continuous bodies of high-grade ore in the Devonian limestone is not regarded as particularly encouraging.

It seems on the whole that the future of Rico is dependent more upon the possibility of working large bodies of low-grade pyritic ore than upon any other factor, to which should perhaps be added the utilization of the sphaleritic ores for the production of zinc. Abundant low-grade pyritic ore is known in C. H. C. Hill, along the Blackhawk fault zone, in the Iron mine, and elsewhere. Unless such ores can be successfully worked, Rico is hardly likely to experience any permanent revival of mining activity, although small bodies of high-grade ore may continue to be found for some time.

But it is desired again to emphasize the personal and fallible character of the foregoing conclusions. The reader is referred to the facts presented in other portions of this report. From them he may draw his own independent deductions.

[1] See Cross and Spencer, loc. cit., pp. 120-123.

DETAILED DESCRIPTIONS OF INDIVIDUAL MINES.

MINES OF NEWMAN HILL AND DOLORES MOUNTAIN.

ENTERPRISE MINE.

Situation.—This, which has been the most productive mine in the district, is situated on Newman Hill, about half a mile southeast of Rico, and about 400 feet above the town. It is reached from Rico by a wagon road, and by a short spur from the Rio Grande Southern Railroad.

Literature and history.—The Enterprise mine has been described in great detail by John B. Farish[1] and T. A. Rickard,[2] each of whom had charge of the development of the mine at different times, and wrote with the advantage which such experience gave. Since their descriptions were published many of the workings have become inaccessible, and all of the large stopes in the so-called "contact" have been allowed to cave in. Consequently the present account of the mine is indebted to these observers for many facts which it is no longer possible to verify.

The following historical account of the discovery and development of the mine is extracted from Rickard's paper:[3]

In the spring of 1881 David Swickhimer, Patrick Cain, and John Gault sunk a shaft 35 feet deep upon their Enterprise claim on Newman Hill. This work was undertaken not upon the evidence of ore, but in the expectation of cutting the continuation of the veins successfully worked in certain claims farther south, owned by the Swansea Gold and Silver Mining Company. Without entering into a detailed description of the geological structure of Newman Hill, it is necessary, in order to make the early story of discovery clear to the reader, to say that the true rock (sandstone and limestone) is overlain by drift, through which shafts must penetrate before reaching the ore-bearing formation. The veins do not reach the present surface, save in the face of the landslip where Harry Irving first detected them. The three owners above mentioned traded their claim to George S. Barlow for $300 worth of lumber. Barlow continued the sinking of the shaft to a depth of 146 feet. On an adjoining claim, named the Songbird, another miner, A. A. Waggener, sank a shaft to the depth of 203 feet. The latter penetrated through the drift into lime shale; but the Enterprise shaft did not at that time reach the true rock. Both shafts got into very wet ground. In the meantime the Swansea workings were reported to be impoverished and, finally, exhausted of ore. It was also said that the veins did not extend northward; but the real fact was that cross veins had faulted the ore-bearing veins in a manner to be rendered clear later on in this account. Newman Hill was discredited, and early in 1883 the Enterprise and Songbird shafts were abandoned.

A year later Larned and Hackett resumed work in the Swansea levels, and by mere accident discovered that the veins had not come to an end, but were simply dislocated. They prosecuted development, proved the continuity of the ore, and made large shipments. Their success induced Waggener and Barlow to relocate their abandoned claims late in 1886. But neither of them had any capital, and they

[1] On the ore deposits of Newman Hill, near Rico, Colo.: Proc. Colo. Sci. Soc., Vol. IV, 1892, pp. 151–164.

[2] The Enterprise mine, Rico, Colo.: Trans. Am. Inst. Min. Eng., Vol. XXVI, 1896, pp. 906–980.

[3] Loc. cit., pp. 909–912.

were unable to overcome the heavy flow of water. In December, 1886, David Swickhimer bought out Waggener's interest, acting on knowledge obtained while working in the Swansea mine, which had satisfied him that the veins must extend into the Enterprise and Songbird claims. In March, 1887, he recommenced the sinking of the Enterprise shaft. In May he acquired one-half of Barlow's interest. In July the windlass was replaced with a steam engine and a pump. All this time Larned and Hackett were driving rapidly northward, and threatened soon to reach the boundary separating their territory from that of Swickhimer and Barlow. Unless the two latter succeeded soon in finding a vein in place, so as to permit a valid location, the claims could be successfully disputed. They therefore hurried the sinking, and in spite of bad luck, floods of water, and a general lack of experience, they struck ore on the 6th of October at a depth of 262 feet. The first assay gave 2.1 ounces of gold and 519.4 ounces of silver per ton.

This ore was 1 foot thick, and formed part of a "flat lode." In the light of later developments this discovery is known to have been a piece of particular good fortune, for the maps of to-day prove that it was the edge of the biggest ore body ever found on Newman Hill, and that a shaft put down 20 feet farther east would have missed it. This was the first evidence of the existence of a flat ore deposit. Swickhimer thought at first that it was merely a roll in the Enterprise—an almost vertical vein. It was, however, soon proved by the workings to be a bedded formation, conformable to the inclosing country. The shaft was sunk 60 feet below this "contact," and a drift was run westward until the increased seepage of water in the following spring proved too much for the pump and caused work to be confined to the contact. In July the water diminished, drifting was resumed, and in August, at a distance of 118 feet southwest of the shaft, the Enterprise vein was at last intercepted. The ore was 20 inches thick and assayed 3.2 ounces of gold and 285.5 ounces of silver per ton.

In May, 1890, the Songbird and Enterprise mines, together with much adjoining property, were acquired by the Enterprise Mining Company.

According to Rickard the workings in 1896 had a total length of 8 miles, and had yielded ore of the gross value of $3,500,000. In June, 1900, the workings had attained an aggregate length of 27 miles, according to Superintendent Percy S. Rider, and the total output had risen to about $4,000,000. The large increase in the extent of the workings and the proportionally small increase of the output are significant. The known "contact" ore bodies had been worked out, and in 1900 active mining for the time being had practically ceased.

Country rock.—The country rock of the Enterprise mine consists of sandstones, shales, and limestones of the lower division of the Hermosa formation (Upper Carboniferous) as described by Cross and Spencer. The total thickness of this division, exclusive of the porphyry sills, is estimated by these writers at about 800 feet, the Enterprise ore bodies occurring nearly midway between the top and bottom beds. The strata, as exposed in the Enterprise workings, have a general strike from N. 60° E. to N. 75° E. and dip southeasterly at from 10° to 15°. Local irregularities, however, are not uncommon, and the beds frequently dip to the southwest, as in the Group tunnel near the Enterprise vein, or even to the northwest.

Several partial sections of these beds have been measured and described. A generalized columnar section is given by Farish[1] in his

[1] Loc. cit., fig. 1.

paper already cited, and two measured sections were published by Rickard,[1] from observations in raises 900 feet apart; while a third, observed in the vicinity of Jumbo No. 2 vein, near raise 15, and published by Cross and Spencer, is reproduced below:

Section near Jumbo No. 2 vein, Enterprise mine.

Top.	Ft.	In.
7. Shale, black, somewhat brecciated	3	0
6. "Contact," consisting of gray pulverulent marly material, sometimes structureless, and sometimes stratified, frequently impregnated with silica, and varying in thickness from 1 to 2 feet	1	10
5. Limestone, dark and impure, breaking with vertical fracture; locally known as "short lime"	1	5
4. Black, fissile shale with occasional lenses of gray sandstone in the upper part	5	0
3. Limestone, similar to the "short lime," but very black with gash veins of quartz	1	6
2. Shale, dark gray in color	1	6
1. Sandstone	8	0
Total	22	3

No particular agreement can be traced in the sequence of the beds in Rickard's two sections—a fact of which he makes rather too much in his later discussion, as will be subsequently pointed out. Perhaps partly on account of an obvious lack of precision in his use of lithological terms, neither of his sections shows any recognizable agreement with that of Cross and Spencer.

To secure a clear presentation of those features of stratigraphy which are essential to an understanding of the ore deposits, a single significant bed may be chosen as a local datum plane, and the strata above and below it briefly described.

The significant stratum selected is a bed of limestone, the familiar "short lime" of the Rico miners. Farish says of it:

It is a grayish deposit, varying in thickness from 18 to 30 inches, and occupies throughout Newman Hill the same stratigraphical position with reference to the other beds. From its close relation to the ore deposits, this band is locally known as the "contact limestone." It is inclosed between two layers of argillaceous shale, which are, however, quite different in appearance. The overlying stratum is a soft, comminuted, drab-colored shale, varying in thickness from 6 to 20 feet. This layer forms an impervious shed to the surface waters circulating above it, thus leaving the mine workings below comparative dry. The underlying bed is a black, finely laminated shale, from 7 to 12 feet in thickness, which rests upon the series of alternating gray sandstones and drab and greenish shales.[2]

Rickard,[3] finding that his sections failed to show stratigraphical agreement, flatly denies the above-quoted statement of Farish as to the persistency of the "short lime" and its superior and inferior

[1] Loc. cit., pp. 914–915. [2] Loc. cit., p. 151. [3] Loc. cit., p. 914.

shales. In this he is in error. Whatever may be true of the sandstones, shales, and limestones above or below the significant stratum, the general description given by Farish is essentially true for that portion of Newman Hill in which lie the workings of the Enterprise, Newman, and Rico-Aspen mines. In fact, Rickard himself, on a subsequent page,[1] speaks of the "contact" as occupying and possessing a genetic relation to a definite stratigraphic horizon.

The "short lime" or "contact limestone" is a light-gray, compact, and apparently unfossiliferous limestone. It effervesces freely with cold acid, but is probably slightly magnesian. It is easily fractured by movements of the rocks, and is frequently traversed by veinlets of quartz. It is sometimes speckled with very minute crystals of pyrite. Its average thickness is perhaps somewhat less than indicated by Farish, as it sometimes thins out to 5 or 6 inches, although it never wholly disappears.

Below this limestone lie the shales referred to by Farish and recorded by Cross and Spencer in their section. They are intercalated with thin beds of sandstone, which may frequently be followed until they wedge out. Thus the proportion of shale to sandstone varies from point to point, although the shale was nowhere found to be entirely absent. Passing downward in the stratigraphic section the shales become less abundant or more arenaceous, and at a depth of 100 feet below the "short lime" fine-grained, greenish-gray sandstones prevail, in moderately thick beds, with a little sandy shale and an occasional band of limestone.

Immediately above the stratum of "short lime" occurs the so-called "contact," which will presently be more fully described. It varies in thickness from 2 or 3 feet up to 20 feet according to Farish, and passes with no very sharp line of demarcation into an overlying bed of black clay shale. As far as known, this shale is never absent, and experience has taught the miners to avoid cutting through it, as when once pierced it is not only exceedingly difficult to retain by timbering, but the opening gives access to abundant descending water, to which the shale in its intact condition presents an *impervious* barrier. Owing partly to this fact, there are at present no opportunities for studying the beds above the shale. They have been penetrated by several shafts, but these are invariably lined with timber. According to the accounts of various men who have worked at sinking these shafts, the beds above the dark shale are chiefly sandstones, and are so soft and broken as to be easily worked with pick and shovel. Mr. Cornelius Williams, for many years foreman of the Enterprise, stated that in these soft overlying beds the thin sandstones and limestones are all more or less shattered and displaced. In the few instances seen, where the top of the shales had been exposed, the overlying rock was a soft sandstone.

[1] Loc. cit., p. 976.

Finally, the surface of Newman Hill is cloaked to varying depths up to about 300 feet by Pleistocene wash, which effectually conceals from view most of the Lower Hermosa rocks.

General character of ore bodies.—The ore of the Enterprise mine occurs in two forms—in almost vertical fissure veins, and in nearly horizontal masses in the so-called "contact," or blanket, immediately above the "short lime," which may be called for convenience of description, the *blanket limestone*. The latter ore masses are genetically connected, not only with the productive or "pay veins" but also with another set of lodes, locally known as "cross veins" and generally barren. Various names have been given to these two systems of lodes, most of them somewhat objectionable in that they involve certain assumptions, or lay stress on more or less artificial distinctions. In this report the "vertical pay veins" of Farish, "verticals" of Rickard, and "pay veins" in the local vernacular, will be referred to as the *northeasterly veins*, from the fact that their courses fall in the northeast and

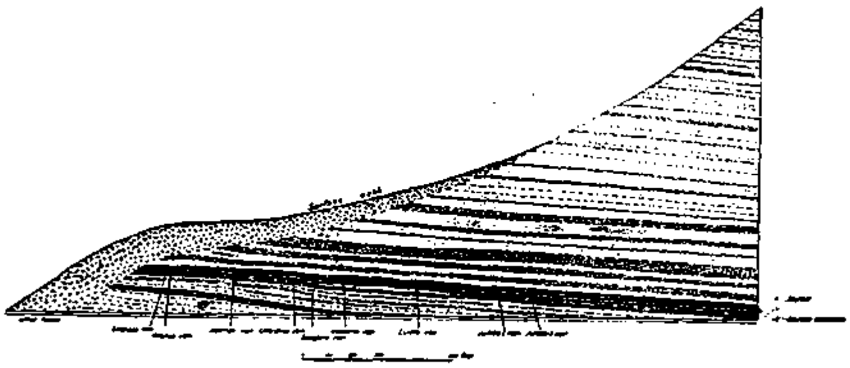
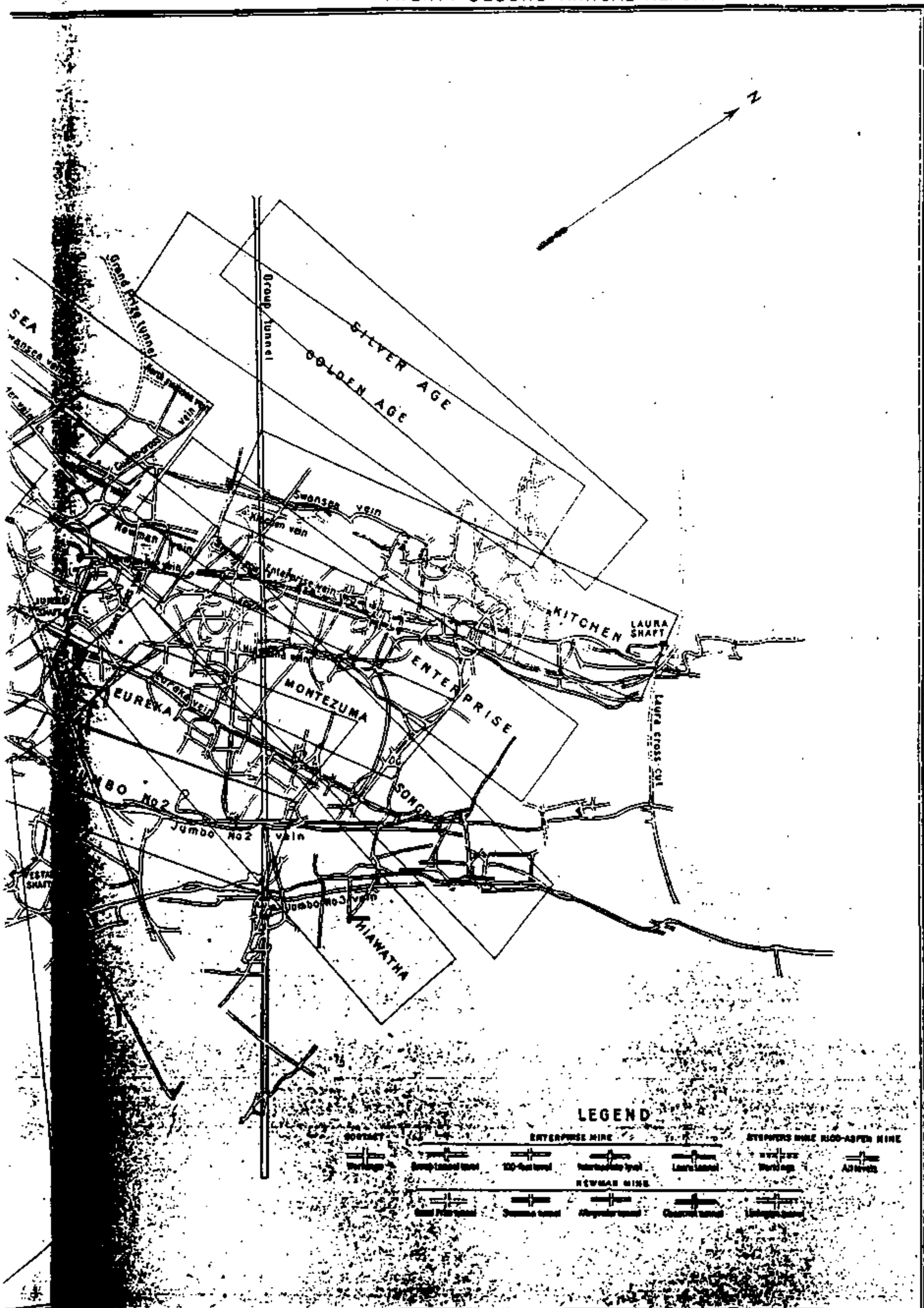


FIG. 44.—Diagramatic longitudinal section through the Group tunnel, Enterprise mine.

southwest quadrants of the compass, while the "cross veins" for a similar reason will be spoken of as the *northwesterly lodes* or *veins*.

Development.—The mine is worked through a straight adit, known as the Group tunnel, about 3,000 feet in length, with a course S. 57° E. This tunnel lies wholly beneath the Enterprise limestone and consequently nowhere cuts the "contact." The latter is a little over 200 feet above the tunnel near its mouth, but is brought down by faulting, and by the general dip of the inclosing beds, to within 35 feet of the tunnel at its breast. The tunnel's course is such that the principal northeasterly veins are cut at nearly right angles. The general relation of the Group tunnel to the lodes and "contact" is illustrated in the accompanying section (fig. 44). As shown by the plan of the Enterprise workings (Pl. XXXVI) there are at least eight important northeasterly veins which have been worked for ore. These are, naming them in order from the tunnel mouth, the Swansea, Kitchen, Enterprise, Songbird, Hiawatha, Eureka, Jumbo No. 2, and Jumbo No. 3



JULIUS BIEN & CO. LITH. N.Y.

CLAIM BOUNDARIES
AND
PRINCIPAL UNDERGROUND WORKINGS
OF THE
ENTERPRISE, NEWMAN, STEPHENS, AND RICO-ASPEN MINES

Scale

veins. The development on the lodes rarely extends for more than 200 feet below the blanket limestone, being practically confined to two levels, one known as the Tunnel level, and one a hundred feet above it, known as the 100-foot level. Immediately above this limestone and following the dip and undulations of its upper surface, is a most intricate and almost entirely irregular labyrinth of drifts and stopes known as the "contact" workings (see Pl. XXXVI).

Connections exist through drifts with the workings of the Newman and Rico-Aspen mines, and also with the surface through the Laura, Stanley, Jumbo, and Enterprise shafts, and an air shaft between the Laura and Stanley. Of these, the air shaft only is now kept open as a manway.

Northeasterly lodes.—These are nearly vertical fissure veins, usually of small size and of very simple type. They rarely exceed 18 inches in width, and the average is probably about 6 inches. As a glance at the map (Pl. XXXVI) shows, they are neither straight nor parallel. Their general courses are as follows:

Courses of northeasterly veins in Enterprise mine.

Vein.	General strike.
Swansea	N. 48° E.
Kitchen	N. 53° E.
Enterprise	N. 50° E.
Songbird	N. 47° E.
Hiawatha	N. 40° E.
Eureka	N. 62° E.
Jumbo No. 2	N. 34° E.
Jumbo No. 3	N. 32° E.

Besides these are the Newman and Intermediate veins, which have been worked to some extent, and many smaller veins that have not proved worthy of development.

The northeasterly veins are so nearly vertical, have been explored through so short a vertical range, and in that distance have frequently shown such variation, or even reversal of inclination, that direct observations of dip angles in the workings now accessible are usually of very little value. It seems to be fairly certain that the general dip of the Swansea is northwest at an average angle of 75° to 80°. The Jumbo No. 3 for about 80 feet below the Enterprise limestone is on the whole practically vertical where seen. Below that it has a decided dip to the southeast of 70° or 75°. The other veins are all nearly vertical, but whether the average dip in any case is southeast or northwest can not be easily decided. The map of the workings indicates a steep southeasterly dip for the Jumbo No. 2, Eureka, and Enterprise veins, but throws no clear light on the Kitchen, Songbird, and Hiawatha veins. Rickard states that "the Songbird dips west flatly;"[1] but in his general section[2] he shows the Songbird first dipping northwest and then turning and dipping strongly southeast. There are other discrepancies in his descriptions and diagrams which detract from their usefulness.[3]

For all practical purposes it is perhaps sufficient to consider the veins as nearly vertical on the whole, with frequent variations to either side of the vertical plane. With all save the Swansea, and perhaps the Kitchen vein, these departures appear to give steep southeasterly rather than northwesterly dips.

The fissures in which these veins formed were opened by very moderate faulting, which so far as observed was normal in character. No case has been noted in which the vertical displacement is over 10 feet, and it is generally much less. In most instances the faulting has thrown down the beds on the southeast side of the fracture. According to the unpublished observations of Mr. Tower, however, the faulting on the Songbird and Jumbo No. 2 veins resulted in a drop of the beds on the northwest sides of the fissure of from 3 to 7 feet. Owing to the condition of the workings, there was no opportunity of verifying these observations in 1900. Rickard's detailed transverse sections[4] make both the Songbird and Jumbo No. 2 veins dip to the northwest and show normal faulting, thus agreeing with Tower and with the general rule of the faulting. But his general section, as already pointed out, shows these veins with a general southeasterly dip. Whether one or other vein actually dips to the southeast or northwest, it may be safely assumed, in the case of veins so nearly vertical and where normal faulting is often plainly shown, both on the principal veins and in small stringers in the country rock, that the stresses which originally opened the fissures were such as produce normal, rather than reversed or thrust faulting.

In the nature of their filling and in vein structure, the northeasterly fissures resemble each other closely, so that the description of a typical vein will apply with little or no modification to all the others. Such a typical vein is the Jumbo No. 3. This, as well as the Eureka, Songbird, and Jumbo No. 2 veins, has been graphically described by Rickard[5] in a series of sketches made from time to time as the development of the mine proceeded. Two of his drawings of the Songbird

[1] Loc. cit., p. 947.

[2] Loc. cit., p. 974, Fig. E.

[3] For example, on pp. 919-920, he states that the Enterprise, Jumbo No. 2, Jumbo No. 3, and Hiawatha veins all dip *northwest*, while the Kitchen, Swansea, and Songbird veins dip *southeast*. In this case the words *northwest* and *southeast* should plainly be transposed.

[4] Loc. cit., figs. 3, 4, and 5, pp. 920, 921, and 923.

[5] Loc. cit., figs. 3-10.

and Eureka, are here reproduced as figs. 45 and 46 in order to show the character of the veins, and for the reason that good exposures are no longer visible.

The Jumbo No. 3 vein was studied in 1900 at several points in the drifts and stopes extending northeastward from the Group tunnel to the Laura cross cut. South of the Group tunnel the possession of this

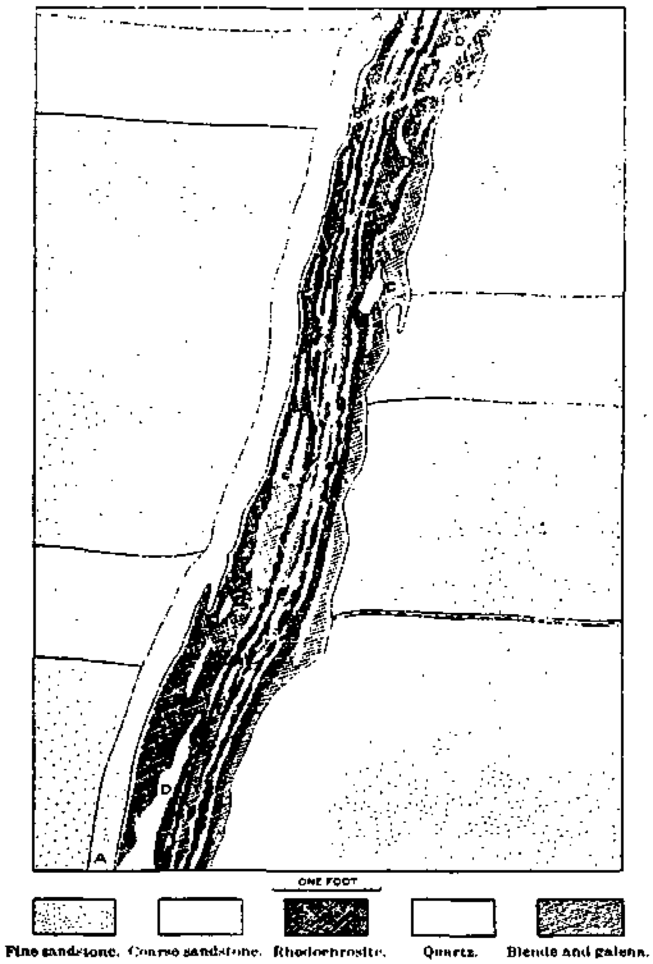


FIG. 45.—Section across the Songbird vein (after T. A. Rickard).

vein was formerly disputed by the Enterprise and Rico-Aspen companies. The bulk of the ore was extracted by the latter, and is reported to have been sometimes over 3 feet wide and rich in argentite and other high-grade silver minerals.

Northeast of the Group tunnel the vein is usually a solid tabular mass or plate of quartz, rhodochrosite, and ore (see Pl. XXVIII, *B*).

It is generally less than 14 inches in width, and is, as a rule, adherent or frozen to the walls of the fissure. Such ore is always banded, and the colors of the component minerals render this structure unusually striking, as may be very imperfectly seen from the illustration, Pl. XXX. But, while striking and beautiful on fresh exposures of the

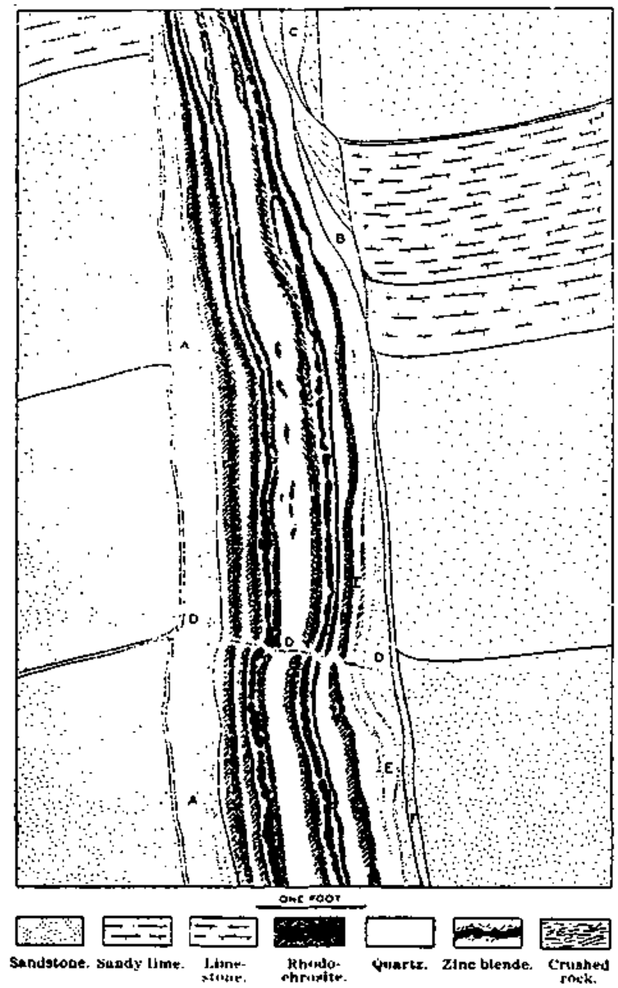


FIG. 46.—Section across the Eureka vein (after T. A. Rickard).

vein, this banding is hardly so regular as Rickard's drawings indicate. Individual bands can rarely be followed far before they die out or coalesce with others. Nor does the succession of minerals from the walls in toward the medial plane of the vein follow any observable regular sequence. Usually quartz was first deposited on the fissure walls, but often rhodochrosite was the earliest mineral to form. The ore minerals, galena, pyrite, chalcopyrite, and sphalerite, occur in all portions of the vein, but tend to be more abundant in the middle. There are usually numerous small vugs along the medial plane of the vein, and in these occur the rich silver minerals proustite, argentite, stephanite (?), and polybasite, and occasionally free gold and silver, which form the richest ore. Sometimes there are other planes of vugs or sutures in the vein, but, as a rule, the medial one only carries rich ore.

Most of the banding, as far as observed, is depositional, i. e., constitutes true banded structure rather than ribbon structure.[1] The minerals have been deposited in successive more or less irregular crusts on the fissure walls until at last only a narrow crevice was left along the medial plane of the vein, in which the richest ore was finally deposited (Pl. XXX). But the deposition was not entirely a simple, uninterrupted process. There is unmistakable evidence, not only along the Jumbo No. 3 vein, but also in others of its class, that the fissure after having been wholly or partly filled with ore, was reopened, usually next to one wall, and the opening again filled by fresh deposition. As far as could be determined, this latter filling always consists of nearly barren white quartz carrying a little pyrite. In some parts of the fissure this reopening and redeposition took place at least twice. Other portions show no signs of it. It was sometimes connected with the local development of ribbon structure on a small scale (see Pl. XXXI).

Thus far the Jumbo No. 3 has been described as a fissure vein of the simplest type. But it does not always retain this character. It is sometimes associated with parallel sheeting of the country rock and is then apt to split up into two or more stringers. This structure is well shown at the north breast of the 150-foot (intermediate) level, near the Laura crosscut, and is illustrated in fig. 40, page 257, where, it will be noted, the vein dips locally to the northwest.

The characteristics of the vein so far described are those which obtain above the Tunnel level and below the Enterprise limestone. In all the northeasterly veins the ore at a certain fairly constant distance below the Enterprise limestone becomes too low grade to pay for working. The veins continue downward and carry pyrite, chalcopyrite, sphalerite, and galena, but the rich ores of silver which made the upper portions profitable are no longer found. The depth at which this change takes place is apparently not dependent upon the topographic surface, but is related to the so-called "contact" resting on the blanket limestone, and with reference to the latter is remarkably small. The relation of the lode pay shoots to the overlying blanket is shown

[1] Following Lindgren. See gold-quartz veins of Nevada City and Grass Valley, etc.: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1896, p. 129.

are very numerous, and are cut at frequent intervals by the long northeasterly drifts. But unless the northwesterly vein is itself drifted upon, such exposures are not sufficient to give the general course and dip, nor do they permit the certain identification of any given northwesterly vein from one drift to another across unknown ground. Such identification is rendered more difficult by the similarity of these veins and their frequent occurrence in groups or zones.

One important zone of northwesterly veins, with a general strike of N. 17° W., and an apparent easterly dip, lies just east of the long crosscut on the 100-foot level, passing east of the Enterprise shaft and crossing most of the northeasterly veins nearly at right angles.

Another prominent northwesterly lode is that which Rickard[1] has represented as faulting the Hiawatha and Songbird veins. This same fissure has been followed apparently in the Kitchen crosscut, between the Songbird and Swansea veins. Toward the southeast its course and identification are less certain. It probably forms one of a group of northwesterly veins which cross the Jumbo No. 3 vein just northeast of the line of the Group tunnel and extend southeasterly toward the Vestal shaft of the Rico-Aspen mine.

A third strong northwesterly lode crosses the north drift on Jumbo No. 3, about 450 feet northeast of the Group tunnel. This fissure has been followed by a crosscut from the Jumbo No. 2 vein to within 200 feet of the Hiawatha, and appears to be identical with a strong lode crossing the Enterprise drift north of the 12½ raise.

A fourth prominent northwesterly lode, having a nearly north and south strike and easterly dip of about 45°, crosses the Eureka vein about 300 feet northeast of its junction with the Jumbo No. 3, and is well exposed in the Laura crosscut.

Besides those mentioned are many other veins belonging to this system, some of which will be referred to when the relation between the northeasterly and northwesterly lodes are described.

The northwesterly lodes vary greatly in breadth, from a mere veinlet or "seam" up to 2 feet, or, according to Farish,[2] 3 feet. In the character of their filling they show, with two or three exceptions, a marked difference from the northeasterly veins. They consist of white quartz, with rarely a little rhodochrosite. The only metallic mineral usually observed in them is pyrite, which may carry a trace of gold and a few ounces of silver, but is not regarded as ore. A striking feature of all these veins which were seen in 1900 is the shattered and crushed condition of their quartz. This can nearly always be picked down with perfect ease and is often reduced to a white powder—"sugar quartz." More or less gouge, formed by the attrition due to recent movement, is rarely, if ever, absent and may constitute the greater part of the material between the fissure walls.

[1] Loc. cit., fig. 23, p. 948.

[2] Loc. cit., p. 157.

Like the northeasterly veins, the northwesterly lodes have been formed with the accompaniment of slight faulting. The greatest vertical displacement recorded has been 25 feet,[1] but it is generally much less than this, and may be only a few inches. In the case of these lodes it is impossible to say how much of this movement has taken place after the original deposition of the quartz. It is the algebraic sum of all the approximately vertical movements since the fissure was first formed.

Relation of the northwesterly to the northeasterly lodes.—It is not intended here to discuss this relationship, concerning which very different opinions have been held, but merely to present the facts upon which rests the more general treatment found on pages 268 to 272 of this report.

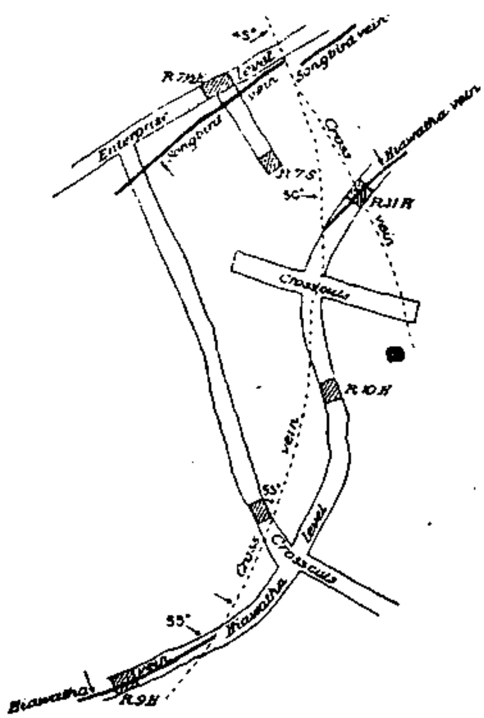


FIG. 47.—Relations of Hiawatha, Songbird, and Enterprise veins, as interpreted by T. A. Rickard.

It has been found that in following the northeasterly lodes they are frequently lost at a point where crossed by a northwesterly fissure. It is commonly assumed by the miners that the former vein is faulted by the latter. In such cases the ore-bearing vein is cut off sharply by the barren northwesterly lode, and by drifting to a greater or less distance along this barren fissure a vein is usually found which is regarded as the continuation of the faulted lode. A notable case in point is the behavior of the Hiawatha vein on the 100 level, about 350 feet northeast of the line of the Group tunnel. At this point the Hiawatha, on drifting northward, was found to be cut off by a strong northwesterly lode. Rickard's and Farish's interpretations of this feature and the steps taken to recover the faulted vein are shown in figs. 47 and 48. According to Rickard, the fault has resulted in a lateral separation of about 175 feet in the case of the Hiawatha and of considerably less than 20 feet in the case of the Songbird, both nearly vertical lodes. It will naturally be asked, On what basis are the supposedly dissevered portions of a vein identified on opposing sides of a

[1] Farish, loc. cit., p. 157.

faulting northeasterly fissure? It may be answered that not only are no certain criteria known where occur so many nearly vertical veins of like character, but that in some cases obviously incorrect identifications have been made, and are believed in by the miners to-day.

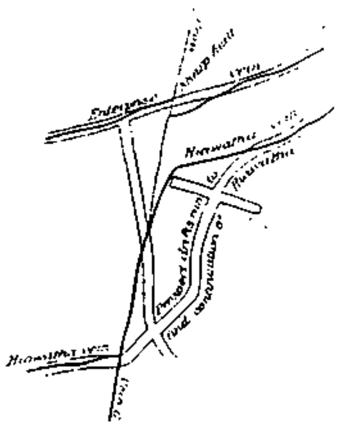


FIG. 48.—Relations of Hiawatha and Enterprise veins, as interpreted by John E. Farish.

The Swansea vein, as seen on the 100-foot level, about 300 feet northeast of the Group tunnel, is cut off sharply by a northwesterly fissure and apparently faulted, with a lateral separation or offset of about 25 feet. The faulting vein dips northeast at an average angle of about 70°, and carries a little low-grade ore. This ore, however, is a breccia consisting of fragments from the Swansea vein, cemented by barren white quartz. This fault is shown in plan on Pl. XXXVI.

About 175 feet north of the Group tunnel, on the 100-foot level, the Jumbo No. 3 vein is cut by one of the prominent northwesterly lodes previously mentioned, and is apparently faulted, its northern continuation being thrown into the hanging wall. From this point northward for a distance of 350 feet, to the supposed junction of the Jumbo No. 3 and the Eureka veins, very little good ore was found. As shown by the sketch plan, fig. 49, the veins in this portion of the mine show many complications, which can not be wholly unraveled with the extent and conditions of the workings as they are at present. There are at least three nearly parallel northeasterly veins known, any one of which may be the actual continuation of the fissure known farther

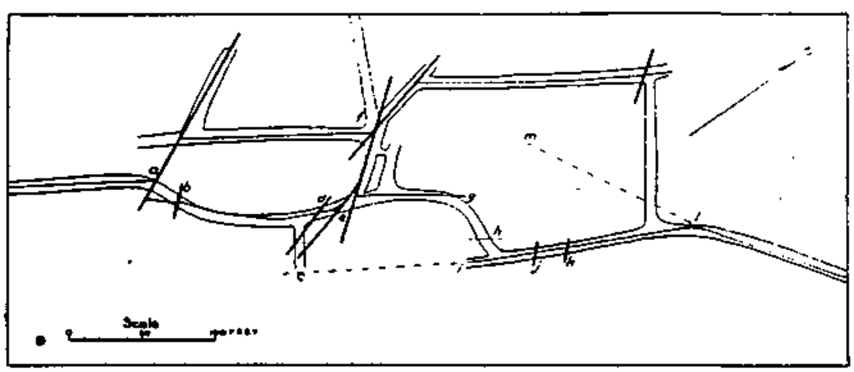


FIG. 49.—Sketch map of a portion of 100-foot level of the Enterprise mine, showing probable relations of the Jumbo No. 3 and other northeasterly veins (in light lines) to the northwesterly lodes (in heavy lines).

south as the Jumbo No. 3 vein. At the point marked *c* in figure 49, the vein *b–d*, supposed to be the Jumbo No. 3, swings abruptly northwest and follows the course of a northwesterly fissure from *c* to *f*, and possibly beyond. This sudden change of the vein from one fissure to another was noted by Farish[1] and was considered by Rickard[2] as an instance of drag due to faulting. Neither observer appears to have been strictly correct in his interpretation. There seems to be little doubt but that the vein *b–d* was originally deflected into the fissure *c–f*, as is shown by the way in which the banded structure and characteristic minerals of the northeasterly vein curve into the new direction. But it is also true that there has been some later movement along *c–f* whereby this original vein has been somewhat broken, and following which a second generation of vuggy white quartz was formed—the usual filling of the northwesterly veins. Still later this composite vein has been crushed and in places reduced to sugar-quartz by the movements which have so strikingly and generally affected the northwesterly veins. This was the only case observed in 1900 where a northeasterly vein could be clearly seen deflected for some distance into a northwesterly fissure. But several other examples have been cited by Farish.[3]

The foregoing examples are those which are at present accessible and appear to throw most light on the relation between the northeasterly and northwesterly veins. But th relation can be better understood and will be more fully illustrated in the description of the Newman mine.

That the tenor of the northeasterly veins is influenced in some manner by the northwesterly fissures is beyond reasonable doubt. Rickard[4] states that "it is common to find ores of more than average grade in the pay veins where they are broken by the cross veins." Superintendent Percy S. Rider informed me that when a northwesterly fissure is encountered intersecting a northeasterly vein, the ore in the latter becomes suddenly poorer or suddenly richer, and the testimony of the miners generally confirms this statement. Mr. Rider also believes that the ore in the northeasterly vein always changes from foot to hanging wall, or vice versa, at such an intersection. But this is certainly far from a universal rule.

The blanket or "contact."—This peculiar and interesting feature of the Enterprise mine has already been referred to and its general position in the sedimentary series pointed out. It is largely an unconsolidated breccia, from a few inches to 20 feet in thickness, which rests bed-like upon the blanket limestone. Its average thickness appears to be about 6 feet. Sometimes the entire thickness is made up of a jumbled mass of small shale fragments embedded in still more finely comminuted

[1] Loc. cit., fig. 9.
[2] Loc. cit., p. 948.
[3] Loc. cit., pp. 158-159.
[4] Loc. cit., pp. 977-978.

shale. In its upper part this breccia passes with no sharp separation into disturbed and crumpled black or dark-gray shale, which becomes less broken in its upper part. Sometimes considerable fragments of soft sandstone are mingled with the shale-flakes in the "contact" breccia. When such is the case the rock immediately above the blanket is usually a bed of similar sandstone, the brecciation having apparently involved the entire thickness of the black shale and a part of the overlying sandstone. There has undoubtedly been some movement within the breccia due to faulting parallel with the bedding, as shown by slickensiding and soft, tough gouges. But this motion has been local, and the blanket as a whole can not be regarded as a simple fault-breccia. In structure and general appearance it suggests a mass of shale and sandstone débris which has been dumped into an empty space. So close indeed is this resemblance that in the New Year mine, where an old tunnel has been filled with waste from more recent workings, a section of this artificial filling perfectly reproduces the characteristic appearance of the blanket breccia.

Not all of the Enterprise blanket, however, is made up of this breccia. Its lower part, resting directly upon the blanket limestone, is commonly a soft, gray, pulverulent, silty material, containing occasional fragments of shale. It sometimes shows nearly horizontal lamination, indicative of a water-laid origin. This deposit varies much in thickness and does not appear to be always present. Between it and the blanket breccia there is no well-marked plane of division.

In certain portions of the Enterprise workings the position usually occupied by the blanket is taken by masses of gypsum, in places at least 15 feet in thickness. A large mass of this gypsum was encountered in the "contact" workings on the south side of the Group tunnel, but could be reached in only one place in 1900. It rests directly upon the blanket limestone, or is separated from it by a variable thickness of the gray, sandy material already referred to. At the only point seen in the Enterprise mine the gypsum showed typically irregular solution forms, and in its relation to the "contact" breccia resembled a mass of snow buried and slowly and irregularly melting away under a landslide. When mining was in progress in this portion of the mine, cavities in the gypsum large enough for a man to crawl through were frequently encountered. The general relations of the "contact" and gypsum are shown in fig. 42, page 275.

Although, on the whole, the blanket, like the strata between which it lies, dips to the southeast at about 10°, yet it presents many local irregularities. Undulations are frequent. One of the most important of these, known as the "Laura swell," is said to occur about 300 feet southwest of the Laura shaft and to be of the nature of a monoclinal fold striking a few degrees west of north. According to Mr. P. S. Rider, in following the "contact" northeast toward the

Laura shaft it is found to rise steeply for a distance of about 60 feet along the incline and then resume its usual gentle dip toward the Laura shaft. Northeast of this Laura swell very little ore was found in the blanket, and the approximate line of the flexure can be recognized on the map of the mine as the northeastern limit of the extensive "contact" workings (see Pl. XXXVII).

Toward the southeast the blanket, as it is followed under Dolores Mountain, near the breast of the Group tunnel, becomes thinner, shows less brecciation, and carries but little ore. No further extensive exploration of it in this direction can be undertaken from the Group tunnel level. The Lexington tunnel, however, 400 feet below, is at its face (which is nearly under that of the Group tunnel) still well below the blanket.

About 2,000 feet from its mouth the Group tunnel passes through a flat seam of crushed shale up to 18 inches in thickness. This material rests upon a bed of limestone and is overlain by dark shale. It is, in fact, a lower blanket of limited extent, but similar to the Enterprise

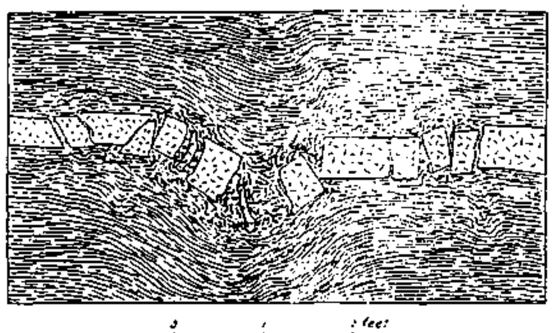


FIG. 50.—Small porphyry sheet intruded in the blanket shales and broken by subsequent movement, Enterprise mine.

blanket above. At this point it is about 100 feet below the latter. At the Enterprise vein the distance is about 140 feet, and this local blanket is said to have carried a little ore alongside the lode.

Eruptive rocks.—Although the prevailing rocks of the Enterprise workings are sandstones, shales, and limestones, a few small masses of monzonite-porphyry have been encountered. One of these is a small, irregular dike cutting the sandstones and shales which form the country rock of the Jumbo No. 3 vein near the Laura crosscut. But the porphyry is more commonly encountered as thin, intrusive sheets. One of these sheets, only from 4 to 6 inches thick, was noted within the blanket itself. It had been intruded in the shales before brecciation took place, and was shattered and displaced. A diagrammatic representation of such a broken sheet is shown in fig. 50. A short distance away from the point shown in this sketch the shales and porphyry become more disturbed and pass into the typical brecciated blanket already described, in which the broken fragments of the porphyry sheet have suffered greater displacement than is here shown. Thicker sheets occur in the blanket and in the thinly bedded sediments above and below it. They are usually rather irregular and have been disturbed by minor faulting. Farish[1] has noted and sketched a decomposed porphyry dike nearly parallel to the Eureka vein and only a few feet from the latter. This dike was not seen in 1900. Farish has described it as being later than the ore. This appears highly improbable, and his error has very likely come from a failure to distinguish planes of faulting from true igneous contacts. One instance was seen in 1900 where a portion of an intrusive sheet had been faulted down so as to cut off the ore in the blanket and give somewhat the appearance of a dike. Its true nature, however, was established by drifting under it a few feet lower down.

Blanket ore bodies and their relation to the lodes.—In 1900 all the known ore bodies in the blanket had been extracted and the stopes allowed to cave. Fortunately, however, the essential facts connected with the blanket ore bodies have been established by Farish and Rickard and are borne out by actual later exploration.[2] These facts may be briefly stated as follows:

Both the northeasterly and northwesterly lodes as they approach within 20 or 30 feet of the overlying blanket begin to split up into stringers, and in the thin-bedded sandstones, shales, and blanket limestone which immediately underlie the blanket these stringers become a network of minute veinlets. The veinlets belonging to the northeasterly lodes usually carry rich ore, but those belonging to the northwesterly lodes are, like the latter themselves, practically barren. The "contact" ore occurs in nearly horizontal masses, capping both the northeasterly and northwesterly lodes. These bodies are from a few inches to 5 or 6 feet in thickness and up to 35 feet in breadth. The ore usually rests directly upon the blanket limestone and has been deposited by replacement of the blanket, particularly of the gray, pulverulent material in its lower part. These general relations are diagrammatically shown in fig. 43, page 291, which is an ideal section across a northeasterly vein and its blanket ore body. Although the ore bodies have been mined out, the behavior of the veins as they approach the blanket may be observed at several points in the mine. The ore bodies, as a rule, have proved larger and richer above some of the barren northwesterly lodes than above the northeasterly veins. But according to Rickard[2] not all of the northwesterly lodes ("cross veins") are capped with ore. The strata beneath the blanket ore bodies generally show greater faulting in the case of northwesterly lode fissures than in connection with northeasterly fissures, and the bulk of the ore lies on the downthrown side (see fig. 43).

The lodes are not known to extend above the blanket limestone. Above the northwesterly lodes, fissures showing evidence of recent

[1] Loc. cit., p. 160, and fig. 80.

[2] Loc. cit., p. 362.

movement sometimes extend upward through the overlying sediments to a distance of 20 feet, and possibly more. But these fissures never carry ore, and may simply be due to post-mineral movement along the lodes below them.

It is known that veins occur on the west slope of Dolores Mountain above the blanket horizon, on the Lone Tree and other claims. They are reported to contain much calcite and some low-grade galena, but have been only slightly exploited, and appear to have no connection with the lodes known in the Enterprise workings. They have never been identified with any veins below the blanket. According to Mr. J. O. Campbell, a vein was cut about 200 feet above the "contact" in sinking the Vestal shaft. It contained no marketable ore. On July 12, 1900, a vein of barren white quartz, about 4 inches wide, was cut 6 feet above the blanket near the Swansea vein.

The splitting up of the veins into a multitude of minute stringers as they approach the blanket, and the associated transformation of a simple fault into step-faulting and flexure in the shales beneath and above the blanket, render very improbable the idea that the veins were continued upward into the rocks above. The movement which resulted in moderate faulting below was dissipated above in more or less irregular fracturing, slipping, and bending of the thinly laminated shales and of the soft, plastic blanket.

The ore was deposited in the blanket partly as an interstitial filling, but more largely by direct metasomatic replacement of the blanket material. In the Enterprise ground it occurs also in irregular masses and bunches in the lower part of the massive gypsum, when that material occurs in the blanket. But one case of such occurence was seen, and the ore, containing some quartz and rhodochrosite, had directly replaced the gypsum.

The blanket breccia, the fine gray silty material of its lower portion, and the underlying blanket limestone have undergone much local silicification over certain portions of the northwesterly and northeasterly lodes. The general appearance of such a silicified portion of the blanket is shown in Pl. XXXIV, *A* from a photograph taken in the so-called Bridal Chamber, over an intersection of the Jumbo No. 3 vein with a large northwesterly lode. At this point the blanket limestone has been shattered, and its fragments, as well as those of the overlying dark shale, have been cemented by pure white quartz. The fragments sometimes preserve sharp outlines, but, often rather shadowy, dark patches and mottlings in the white quartz. In either case they are themselves converted into fine quartzose aggregates, and contain no carbonates. As a rule such strong silicification and the deposition of ore in the blanket appear to be antagonistic processes. At least where the one occurs the other is generally lacking, or is subordinate.

The ore.—There is no sharp mineralogical distinction to be drawn in the Enterprise mine between ore from the northeasterly veins and "contact" ore. Galena and sphalerite occur in both and are associated with one or more rich silver-bearing minerals, including polybasite, stephanite,[1] argentite, and proustite. Specimens of rich blanket ore often show polybasite in crystals having the characteristic six-sided, tabular prismatic forms, with triangular striations, that are common with this mineral. Chalcopyrite in comparatively small amounts occurs in both blanket and lode ores, whereas tetrahedrite was noted only in specimens of blanket ore, but may occur in the lodes also, as stated by Farish,[2] and is found in the Selenide lode, in the Rico-Aspen mine. Quartz and rhodochrosite are the common gangue minerals in both classes of ore, the rhodochrosite being regarded as a rough indication of good ore. The latter, however, is less abundant in the blanket ore than in the northeasterly veins. Where the blanket ore has replaced massive gypsum, the clear crystalline variety termed selenite is usually present and forms with quartz and rhodochrosite, the gangue of the ore.

The chief difference between the lode and blanket ores is structural. The lode ores are nearly always banded parallel to the walls of the fissure. The blanket ores, on the other hand, are massive.

The ore of the Enterprise varies widely in value. The average during one year was about 200 ounces of silver and 2 ounces of gold per ton. One carload of about 10 tons is recorded, which was worth about $8,000. The gold has usually ranged from 0.5 to 3 ounces, the silver from 100 to 200 ounces, the lead from nothing up to 10 per cent, and the zinc up to 15 per cent. The silica ranges from about 25 per cent to 60 per cent. Rickard[3] has published the approximate compositions of first- and second-class ores as derived from analyses, and his figures are given below:

Composition of Enterprise ore.

Constituent.	First class.	Second class.
	Per cent.	*Per cent.*
SiO_2	29.2	50–55
Mn	2.0	6–10
Fe	11.8	6–10
Zn	12.0	5– 7
Pb	10.2	2– 3
S	11.6	5– 8
Au	a 0.87	a 0.3–0.5
Ag	a 221.50	a 45–75

a Ounces per ton.

[1] Given on the authority of Farish (loc. cit., p. 161), who also records pyrargyrite and native silver. All of the so-called "stephanite" seen in 1900 proved to be argentiferous galena.

[2] Loc. cit., p. 161.

[3] Loc. cit., p. 912.

Rickard remarks that the first class was mostly "contact" ore, while the second class represents the principal product of the veins.

The pyrite which sometimes occurs in the northwesterly lodes usually contains traces of gold and up to 8 or 10 ounces of silver per ton, but is never rich enough to work.

NEWMAN MINES.

Situation and history.—These, which in reality constitute but one mine owned by the Swansea Gold and Silver Mining Company, are also on Newman Hill and are worked through several adits about 1,000 feet south of the mouth of the Group tunnel and at nearly the same level as the latter. The general relation of the workings to those of the Enterprise mine may be seen from the combined plan forming Pl. XXXVI. It was from the Chestnut vein in this property that the first ore was shipped from Newman Hill in 1879, and this discovery led ultimately to the opening of the rich ore bodies in the Enterprise and Rico-Aspen mines. The Newman mines were worked actively in 1884, after a period of idleness, and have continued in intermittent operation to the present time. The blanket ore bodies, however, were not nearly so large as in the Enterprise, and of late years the mine has produced but little ore and has been operated on the leasing system.

Development.—The mines are worked through three principal levels known as the Chestnut, Klingender, and Swansea. All three communicate with the surface through adit tunnels opening on the steep hillside at slightly different elevations. There are in addition various minor drifts and crosscuts at other levels, and fairly extensive "contact" workings. A number of northeasterly lodes have been exploited, of which the more important are the Chestnut, Newman, Newman No. 2, Klingender, South Klingender, and Swansea. The Newman No. 2 is in all probability the same as the Enterprise vein.

Country rock.—In all that concerns country rock and general occurrence of the ore, the Newman mines are merely continuations of the Enterprise mine already described, and it is unnecessary to repeat those general descriptions. The general dip of the beds is about 15° a little west of south.

The lodes.—As in the Enterprise mine, these fall into two classes—the northeasterly veins, which carry workable ore for 200 feet or less below the contact, and the barren northwesterly lodes. The relations of these lodes to each other and to the overlying blanket are in general those observed in the Enterprise, but there are many details obtainable in the Newman mines which can not be so easily seen in their larger neighbor. The northwesterly lodes in particular are not only well developed in the Newman workings, but have been drifted on for long distances, and have thereby been well exposed.

The northeasterly veins in the Newman workings average 6 or 8 inches in width, although much wider portions are said to have been stoped out. Banded structure is a very common feature, and the medial plane of the vein is often marked by vugs lined with quartz crystals. The pay ore has, as a rule, an even more limited vertical range than in the Enterprise mine. Frequently a vein carrying rich ore just beneath the blanket becomes too poor to work at a depth of 70 or 80 feet below the blanket limestone. The ore, unlike that of the Enterprise, is more or less oxidized, the rhodochrosite being partly converted to black oxide of manganese and the argentiferous sulphides partly reduced to native silver.

The Chestnut lode, which is accompanied by two or more nearly parallel lodes, and is crossed by several northwesterly lodes, has been followed in from the surface for a distance of about 450 feet, until it is lost at the intersection of a northwesterly lode known as the Stephens "cross vein." The general dip of the Chestnut is northwest at from 50° to 70°. The lode is partly a sheeted zone comprising 3 or 4 stringers up to 3 inches wide, separated by slabs of country rock. The pay ore, as seen in a stope just above the Chestnut level, was less than 1 foot wide and partly oxidized, containing native silver.

A crosscut, driven north for about 100 feet from the Chestnut lode, cuts several small veins, both northeasterly and northwesterly, and finally taps the Newman vein, which has been drifted upon for about 800 feet. Where intersected by the crosscut, this vein is 8 inches wide and dips northwest at 75°. It is a solid, banded vein, frozen to its walls. Toward the northeast the vein becomes larger and in places fills a sheeted zone as much as 2 feet wide. Comb structure is a common feature. Some portions of the vein have been brecciated and the fragments roughly cemented by quartz, leaving many interstices unfilled. The vein is cut off in this direction by a strong northwesterly fissure known as the Cuarto "cross vein," and its continuation is supposed by the miners to be offset about 90 feet to the north. This point, however, will be more fully discussed later. The supposed displaced portion of the Newman vein, beyond the Cuarto cross vein, is in the line of the Klingender vein, to be described later, and is known as the Newman vein in the Enterprise mine. It is notable in having contained good ore to a depth of 140 feet below the blanket in the Newman workings.

The Newman No. 2 vein is a simple plate of banded quartz, rhodochrosite, and ore, about 6 inches in width and nearly vertical. This vein is not known west of the Cuarto cross vein, near which it splits up into stringers. On the northwest it is slightly offset from the Enterprise vein along a small northwesterly fissure.

The Klingender vein lies from 80 to 100 feet northwest of the Newman vein proper, and has been drifted upon from the surface for a times interrupted by a northwesterly lode in a manner that can not certainly be ascribed to a simple faulting of one vein by another. It

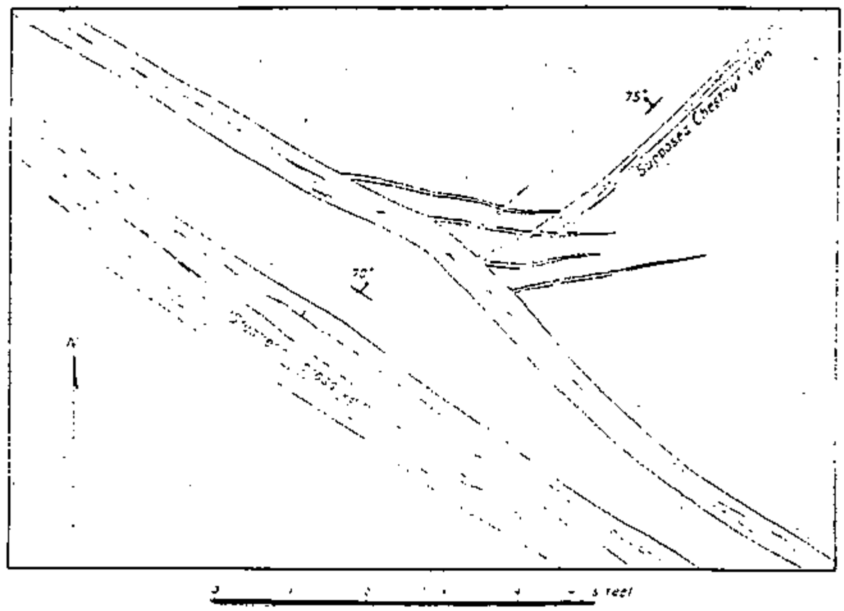


Fig. 51.—Plan of junction of the Stephens cross vein and the supposed northeastern continuation of the faulted Chestnut vein.

is proposed to illustrate the foregoing statements by several examples.

The Chestnut vein, at the point where it meets the Stephens cross

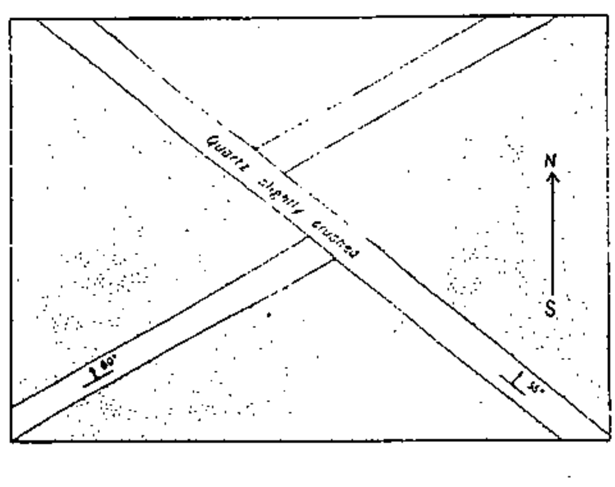


Fig. 52.—Plan of northeasterly stringer faulted by northwesterly stringer in roof of crosscut from the Chestnut vein to the Newman vein, Newman mine.

vein, is cut off sharply and its northeastern continuation is lost. It is supposed by those working the mine that the vein is faulted, and that its northeast portion has been offset about 100 feet to the southwest, where a small vein was found going off northeast from the Stephens cross vein (see map, Pl. XXXVI). This vein begins as a series of small, tight stringers, which gradually collect into a narrow but rich vein. The relation of this vein to the Stephens is indicated in fig. 54. The small stringers shown are perfectly tight, and the Stephens lode itself reveals but slight evidence of recent movement at this point. It

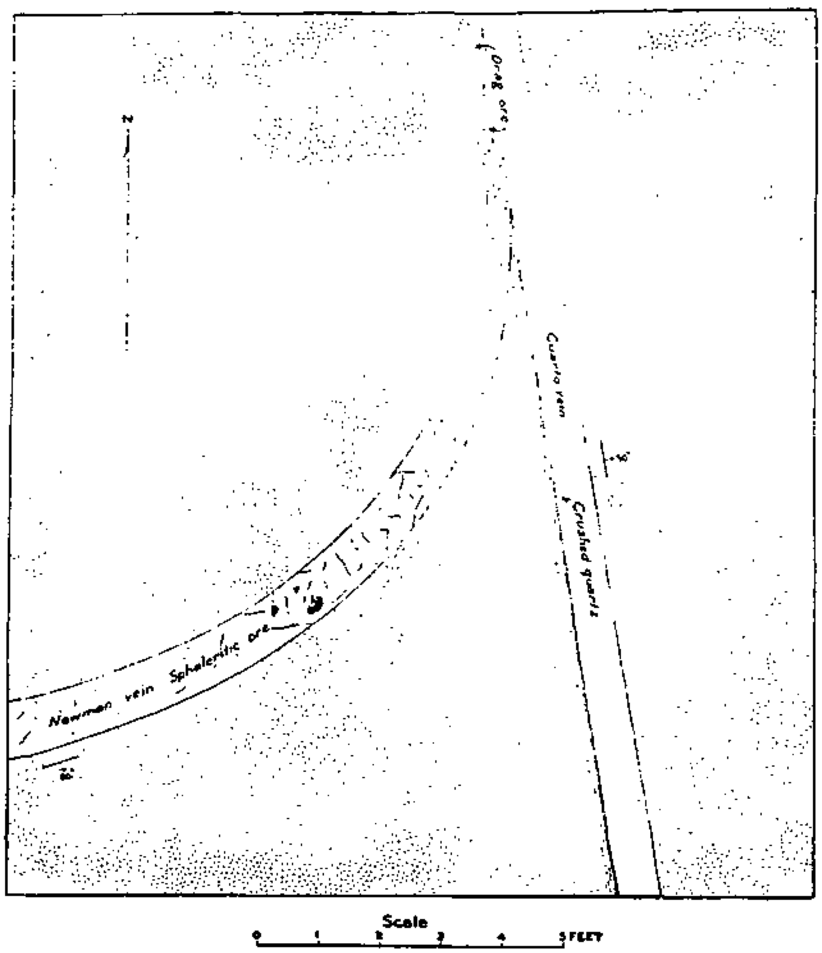


FIG. 53.—Plan of junction of the Newman vein with the Cuarto cross vein.

is plain from the sketch that the relation of the small northeasterly vein to the Stephens lode is not a simple dislocation of one lode by another. Furthermore, a fault which could result in a horizontal displacement or offset of 100 feet could hardly fail to fault the overlying blanket and the Newman and Klingender veins to a like extent. Neither of these veins, however, shows any apparent faulting by the Stephens lode.

Several small northeasterly and northwesterly veins or stringers are cut in the crosscut from the Chestnut to the Newman vein. Two of these veins intersect in the roof of the crosscut, and the northwesterly fissure faults the other about 3 inches, as shown in fig. 52.

About 8 feet west of the point where the crosscut enters the Newman vein, the latter is cut by a strong northwesterly lode (also visible in the crosscut) of barren crushed quartz. There is no recognizable faulting of the Newman vein.

Where crossed by the South Klingender cross vein, the Newman vein is pinched and splits up into stringers, but is not noticeably displaced. The northwesterly lode here consists of crushed quartz, and is about 2 inches wide.

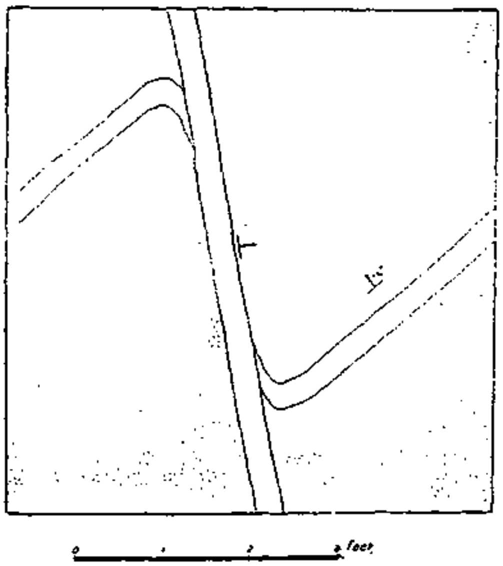


Fig. 54.—Plan of South Klingender vein faulted by the South Klingender cross vein.

Toward the northeast the Newman continues as a strong, fairly regular vein until it reaches the Cuarto cross vein. Within 4 or 5 feet of the latter, the Newman vein bends abruptly north and persists for about 15 feet along the foot wall of the Cuarto lode as crushed and dragged ore (fig. 53). It is commonly supposed that the Newman vein is offset at this point by faulting, which has effected a horizontal displacement of 90 feet, throwing the northeast portion of the Newman vein into line with the Klingender vein.

This supposed continuation of the Newman vein is cut by the James cross vein, and is distinctly faulted, the northeast portion being offset about a foot to the northwest. This northwesterly fissure also faults the Newman No. 2 vein in the same manner, the offset in this case, however, being only about 6 inches.

Along the Klingender vein several small faults were noted along northwesterly fissures. The South Klingender cross vein faults the Klingender normally, offsetting the northeastern portion about 2 feet to the southeast.

The South Klingender vein is faulted by the South Klingender cross vein, as shown in plan in fig. 54. The northeasterly vein is curved and dragged to some extent along the fault plane.

In general it may be said that the demonstrable faults in the Newman mines are small in throw and normal in character.

RICO-ASPEN MINE.

Situation and development.—This mine is situated on the southwestern slope of Newman Hill, just north of Deadwood Gulch. As shown on Pl. XXXVI, its workings are contiguous to those of the Enterprise and Newman mines. Large amounts of rich ore were produced subsequent to the purchase of the mine by the present company in 1891. This ore was obtained chiefly from the veins and "contact" workings in the northern part of the mine in ground at that time in dispute between this company and the Enterprise Mining Company. Of late years but little ore has been shipped, and that has been mined by a few leasers. All of the old "contact" workings and a large proportion of the drifts are no longer accessible.

Country rock.—This is the same as that found in the Enterprise and Newman mines, including the persistent bed of blanket limestone. The general dip is from 10° to 15° to the southwest. Inspection of the geological map (Pl. XLI) shows that this is also the dip of the strata near the mouth of Deadwood Gulch, the direction of strike swinging around to the west in accordance with the main domical structure, of which the town of Rico occupies almost the central point.

Access to the workings was formerly gained through five shafts—the Aspen, Vestal, Jumbo, Montezuma, and Silver Glance shafts. The present adit is the Syndicate tunnel, nearly 3,000 feet in length. For 900 feet the tunnel has a southeast course. It then turns about S. 73° E. and continues on this course to the face, which could not be reached in 1900 on account of the presence of gas. The Stephanite tunnel, which enters the hill just north of Deadwood Gulch, has a course of N. 72° E. for about 700 feet, and connects with drifts and crosscuts from the Syndicate tunnel. It is now caved in. The Syndicate tunnel is only a short distance below the blanket which comes down to this level at the Silver Glance shaft, a short distance south.

The lodes.—Owing to the condition of the workings no satisfactory study could be made of the lodes in the Rico-Aspen mine. They are for the most part, however, direct continuations of those worked in the Enterprise mine, and are of similar character. The Syndicate vein is the same as that known as the Stephens, farther northeast, and as the Eureka in the Enterprise ground. The Jumbo No. 2 appears to correspond with the Jumbo No. 2 in the Enterprise, and the Star is probably the Jumbo No. 3. The latter may, however, be represented by the Selenide vein. The exact relations of the Jumbo, Montezuma, and so-called Montezuma-Jumbo veins could not be ascertained.

The Selenide vein, which was being worked by leasers in 1900, has an average width of less than 6 inches and is usually frozen to the walls. It has a dip of about 85° to the northwest. It is filled with banded ore in every way similar to that already described in the northeasterly veins of the Enterprise mine.

As a rule, and excepting the disputed territory on the northeast, the veins are smaller and not as rich as in the Enterprise workings.

Northwesterly lodes are numerous in the Rico-Aspen workings, and many of them are well exposed in the Silver Glance drift, which connects the shaft of that name with the Syndicate tunnel. These, as elsewhere in Newman Hill, are filled with barren white quartz, showing more or less crushing. They are generally accompanied by slight

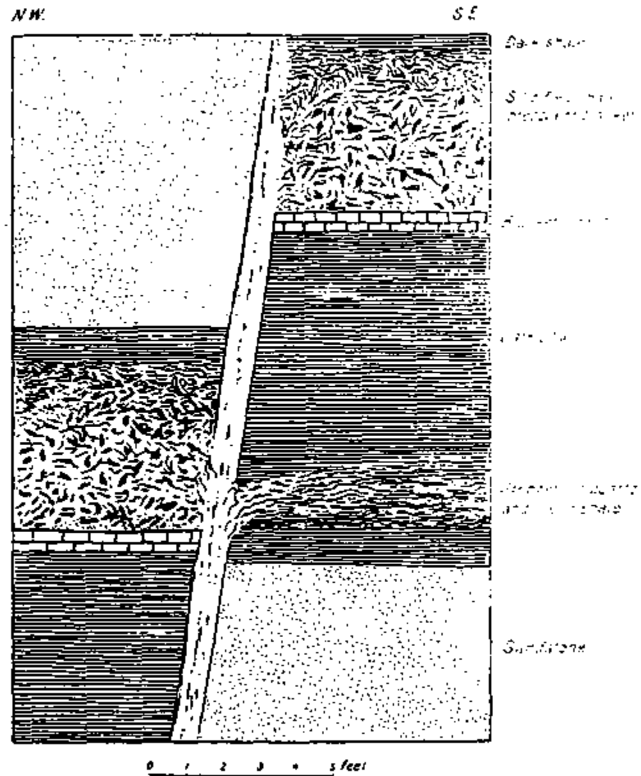


FIG. 55.—Diagrammatic section through the Montezuma vein, showing faulting of blanket and occurrence of a second ore-bearing horizon below the blanket limestone.

normal faulting, the maximum displacement observed being about 5 feet.

The blanket.—But little of this can now be seen in the mine, but the portions visible are of considerable interest. Above the Montezuma vein, just north of the Syndicate tunnel, the blanket is reached at 60 feet above this level. It resembles closely that described in the Enterprise mine, but is here subject to more sudden rolls and changes of dip. In places it has also undergone considerable differential movement, as shown by very irregular slip planes traversing the soft shale breccia. These are particularly abundant in the upper portion of the blanket, just below the less disturbed black shales forming the roof. The general dip of the blanket is southwest at from 10° to 20°.

Near this point the Montezuma vein is cut by two northwesterly veins. The southern one faults the Montezuma, offsetting the northeast part of this vein a few feet to the southeast. Above the intersections of these veins the dark shale breccia has been beautifully silicified by white quartz. All the finer material of the breccia has been replaced by pure white quartz, while the larger fragments, partly silicified, persist as more or less shadowy dark mottlings in a dazzling white matrix. No ore was seen in the blanket at this point.

The Montezuma vein (or a spur from it) faults the blanket above it as shown in fig. 55. The dislocation is normal, and the vertical displacement is about 8 feet. A portion of the vein turns off flatly into

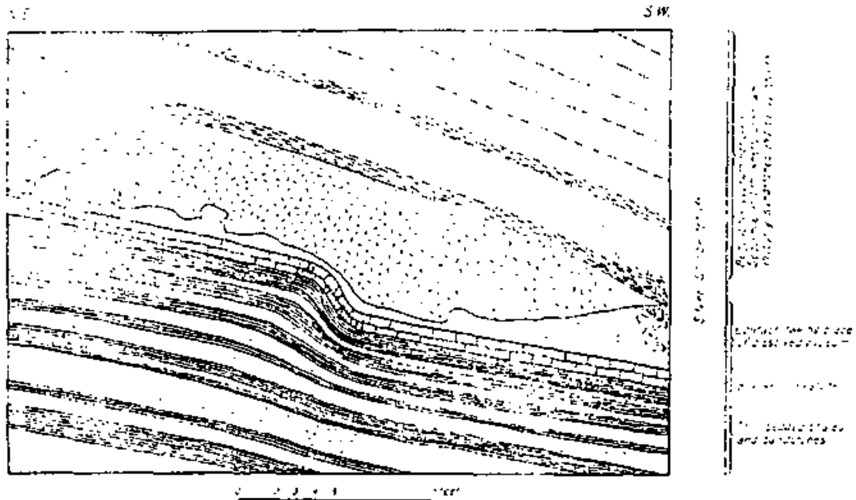


FIG. 56.—Partly diagrammatic sketch of the gypsum "contact" and inclosing beds at the Silver Glance shaft, Rico-Aspen mine.

a bed of shale below the stratum of blanket limestone, and has formed a nearly horizontal bunch of stringers and some ore, constituting a local ore horizon below the main blanket (see fig. 55).

In the vicinity of the Silver Glance shaft large masses of gypsum, occupying the stratigraphic position of the blanket, are well exposed, and excellent sections of the rocks immediately underlying the blanket horizon are obtainable in the Selenide drift near this shaft.

The gypsum forms a solid, massive, crystalline bed, the maximum thickness of which is unknown, but which is probably considerably over 6 feet. When drifts are run under this gypsum, the underlying thin-bedded shales, sandstones, and limestone cave away up to the gypsum, leaving the under surface of the latter as a solid roof. As a rule this surface is very even and dips to the south at about 25°.

Wherever it presents such regularity it rests directly upon the blanket limestone with no trace of the usual blanket elsewhere found at this horizon. In such cases there is no ore found.

But the under surface of the gypsum is not always even. It is sometimes irregularly corroded or dissolved away so that it becomes pitted with rounded cavities, up to 8 feet in diameter, resembling inverted potholes. Groups of these cavities are shown in Pls. XXXII and XXXIII, *A*, which are from photographs taken just north of the Silver Glance shaft, and a section across such a group is shown in fig. 56. When such cavities are first opened they are reported to be usually partly filled with loose, spongy "gypsum." Wherever the gypsum shows no solution it rests snugly upon the blanket limestone with a perfectly sharp and tight bedding contact. But wherever solution has attacked the underside of the gypsum, more or less of the gray pulverulent material, already described as a characteristic feature of the bottom of the "contact" in the Enterprise mine, always lies upon the limestone (see fig. 56).

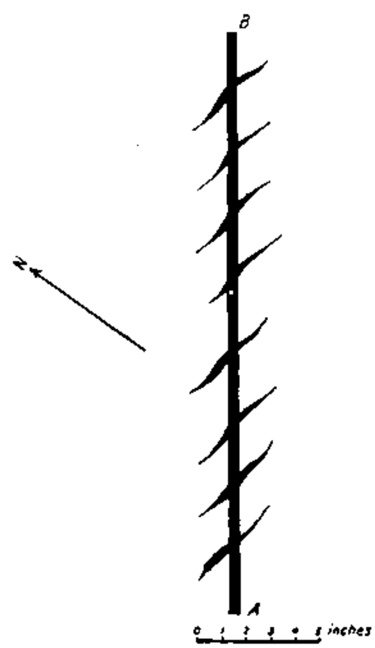


Fig. 57.—Plan of small gash viens produced on underside of gypsum by the dying out of a stringer, which appears a few inches below as the straight veinlet A–B.

Toward the south the gypsum thins out and disappears at the Silver Glance shaft, where its place is taken by the usual silty "contact" material up to 4 feet in thickness, grading above into a breccia of shale and sandstone. This thinning and final disappearance is undoubtedly the result of the removal of the gypsum by solution. The general relations of the gypsum to the blanket and to the inclosing beds are shown in fig. 56, which is a sketch of the side of the Silver Glance drift just northeast of the shaft.

The thin-bedded sandstones and shales which underlie the persistent bed of blanket limestone are well exposed at the point of the above sketch and also in the Selenide drift near by. In this drift the splitting up of individual beds of sandstone or shale 3 or 4 inches thick into several thinner beds and the frequent complete wedging out of the latter can be plainly seen. These very thin beds, particularly the shales, are frequently locally distorted and even thrown into small overturned folds, although more massive beds above and below them are not noticeably disturbed. It is but a step from such a deformed bed of shale to the production of a shale breccia identical with some of the so-called "contacts" of this region. The bed of limestone immediately beneath the gypsum is without much doubt the same as the bed underlying the blanket in the Enterprise mine. In this portion of the Rico-Aspen workings, however, there is a second very similar bed, stratigraphically a few feet below it.

Near the Silver Glance shaft the Selenide drift is so close to the blanket horizon that the Selenide vein does not appear as a simple vein, but is split up into a multitude of small stringers of white quartz. Some northwesterly veins which occur at this point exhibit similar behavior. These stringers are usually less than 1 inch in width and are very numerous. They show a general tendency toward parallelism with a course of N. 55° E. They all die out at or before reaching the bottom of the bed of gypsum. Many are mere gash veinlets, dying out above and below in the thin fissile beds below the blanket limestone. Stringers which reach the bottom of the gypsum, or rather a thin shaly skin adherent to its under surface, frequently split at the point of disappearance into a curious linear system of gashes, represented in fig. 57. One or two stringers were noted passing up into the silty blanket material which underlies the corroded gypsum, as if they were of later date than the formation or deposition of this substance.

South of the Silver Glance shaft the blanket can no longer be reached. All accounts agree that it contained ore and that it acquired in that direction a steeper southerly dip. At or near the line where the geological mapping indicates the existence of the Deadwood fault the blanket and its ore grew thinner and suddenly turned down with a steep dip to the south, so that it could no longer be followed without sinking.

LEXINGTON TUNNEL.

This tunnel was driven at a cost of $64,000 to undercut the workings of the Newman and Enterprise mines. It has a straight course of S. 75° E., and a length of 3,000 feet. It cuts the Newman Hill lode systems about 350 feet below the lowest level of the Enterprise, and has a connection with these upper workings through the old Jumbo shaft, about 70 feet north of the tunnel and about 1,900 feet from its mouth. This shaft is 950 feet deep and extends 65 feet below the Lexington tunnel. According to Mr. Charles Newman, its bottom is in porphyry, immediately above which is some soft, broken shale, constituting a kind of "contact."

The Lexington tunnel is mainly in massive sandstone of the Lower Hermosa, with subordinate lodes of shale. The general dip is S. 35° W. at from 10° to 15°. Several veins are cut belonging to the northeasterly and northwesterly systems, but at this depth they are all small and relatively barren. The breast of the tunnel could not be reached by about 500 feet, but no vein was observed over 6 inches in width, and none which carried workable ore. The Eureka-Stephens syndicate vein crosses the tunnel about 75 feet west of the crosscut connecting with the Jumbo shaft. A few feet west of the vein a dike about 15 inches in width was cut. Its course is about northeast and southwest, and it dips west at 75°. The rock is much decomposed, but appears to be a fine-grained diabase, distinctly different from the usual gray monzonite-porphyry, common as intrusive masses in the Lower Hermosa sediments. This is perhaps the same dike noted by Farish in the Enterprise mine.

No ore has been taken from the Lexington tunnel. It affords, however, a starting point for prospecting farther eastward, under Dolores Mountain, than is possible from the Group tunnel, which, on account of the general southeasterly dip of the strata, can not be continued much farther without cutting through and coming out above the Enterprise blanket. The indications for the existence in this direction of profitable bodies of blanket ore, and productive veins yet undiscovered, are not altogether encouraging. Yet it is difficult to find a good reason for driving the Lexington tunnel thus far, unless it was intended to carry it farther.

GOLDEN FLEECE OR NEW YEAR MINE.

This mine, which is not at present of great economic importance, is yet of considerable interest. It lies at an elevation of about 9,050 feet on the west slope of Newman Hill, near the southeast corner of the town of Rico. It is entered by an adit tunnel about 200 feet below the Group tunnel, and, although from 50 to 100 feet higher than the Lexington tunnel, this adit penetrates beds stratigraphically lower than those seen in the latter.

The tunnel enters in porphyry, apparently near the upper part of the thick sheet of monzonite-porphyry mapped by Cross and Spencer, and by them described as intrusive into the Lower Hermosa sediments and attaining a thickness of 500 feet. It is without much doubt a portion of the same mass in which the Skeptical shaft is sunk, which is reached in the bottom of the Jumbo shaft, 65 feet below the Lexington tunnel, and which is encountered in the diamond drill hole driven from the floor of the Syndicate tunnel.

The tunnel, from the mouth in, follows a vein in the porphyry for several hundred feet. This vein strikes about N. 75° E. and is practically vertical. It is usually simple, about 6 inches wide, and is frozen to its porphyry walls; but it sometimes divides into tight stringers. It carries sphalerite, galena, and pyrite, and is low in grade. Above this vein, and resting upon the upper surface of the porphyry sheet, which dips to the south, is a "contact" carrying some ore. At the point first seen, this blanket is about 5 feet thick. At its bottom, resting upon the porphyry, is about 8 inches of crushed quartz containing sulphides—chiefly pyrite. Above this is 18 inches of soft shale breccia, then about 6 inches of disturbed black or dark-gray shale. Above this rests 2 to 3 feet of soft, gray, somewhat calcareous shales, which are crushed and disturbed and sometimes reduced to a gray clay. The top of the blanket was not visible at this point. The fragments of shale are usually impregnated with fine pyrite. There is not always a sharp line between the dark and light shales and the latter are, in part at least, bleached and altered forms of the former.

Above veins which enter it from below, the blanket breccia is frequently cemented and silicified by quartz carrying pyrite. In such cases the shale fragments can be recognized merely as siliceous blotches, of uncertain outline, surrounded by white quartz.

In the southern part of the workings the porphyry sheet can be seen dipping down at about 30° in a direction S. 25° E. Its contact with the shales is plainly an eruptive one, although the sheet in general follows the bedding planes. The blanket breccia does not always rest directly upon the porphyry, but is sometimes separated by a varying thickness of shale.

The blanket ore, of which not much was seen, consists chiefly of chalcopyrite, pyrite, galena, and sphalerite in a somewhat spongy quartz gangue. It is entirely different in character and much lower in grade than the ore of the Enterprise blanket, from which it is separated by fully 400 feet of strata. The two contacts are different, not only in character, but probably in origin.

UNION-CARBONATE MINE.

Situation.—Perched at an altitude of 10,400 feet on the northwest spur of Dolores Mountain, the shaft house of this mine is easily seen, on looking due east from Rico, as the highest of the mine buildings that dot Newman Hill. It lies just a mile east of the town in a straight line, but is reached by a road which zigzags up the slope of Newman Hill and passes over into Allyn Gulch.

History.—Work on the mine began in 1879, when two tunnels run in from the hillside struck the same ore body, and litigation followed. From 1880 to 1887 the mine lay idle. Then after spending some $25,000 at law, the contestants agreed to work the mine together. Operations were resumed, and ore was extracted until 1894. The total product has been about $100,000, although the workings are more extensive than in many mines which have produced several times that amount.

Development.—The mine is opened by a shaft 256 feet deep, and by three tunnels connecting with the shaft on two main levels at 190 feet and 210 feet below its collar. A rough sketch map of the principal workings (based on hand-compass readings and pacing) is shown in fig. 58.

A fourth tunnel, known as the Fickle Goddess tunnel, has been run in from the side of Newman Hill, on a course N. 83° W. for a distance of 682 feet. This is intended to connect with the deepened Union-Carbonate shaft about 800 feet below its collar.

Country rock.—This is in general the same as in the Enterprise sandstones and shales of the Lower Hermosa, with an occasional bed of limestone. The general dip is southeast or east at 10° to 15°. These

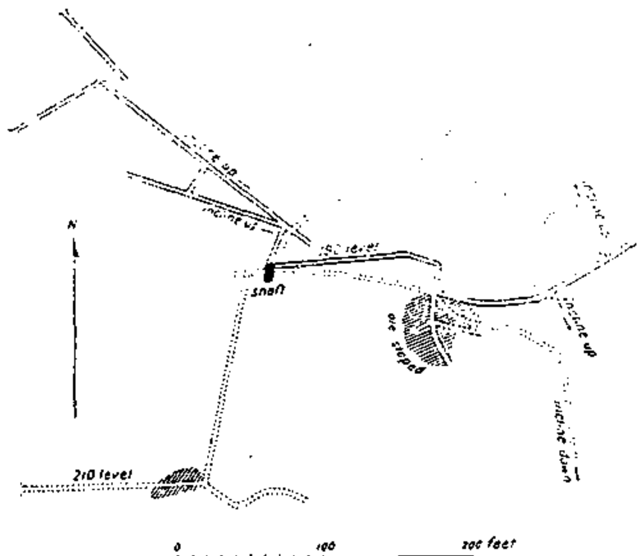


FIG. 58.—Sketch plan of the principal workings of the Union-Carbonate mine.

beds are cut by sheets and dikes of monzonite-porphyry. The sheet-like intrusions are more numerous than in the mines farther south, and appear to have directly influenced the ore deposition. Although the workings in all probability pass through the same stratigraphic horizons that are encountered in the Enterprise, Newman, and Rico-Aspen mines, yet the characteristic blanket of these mines, with its underlying blanket limestone, overlying shales, and included masses of gypsum, can not be identified in the Union-Carbonate, where ore deposition took place under different conditions.

Occurrence of the ore.—The country rock of the Union-Carbonate mine is traversed by numerous vertical veins, which show but few points of resemblance to those seen in the Enterprise mine and in the southern part of Newman Hill. A few fissures have a nearly north-and-south course, but these are relatively unimportant. By far the greater number strike from N. 60° W. to N. 75° W. It will be remembered that the northwesterly fissures of the Enterprise and neighboring mines rarely depart more than 45° from a north-south course, the divergence usually being only a few degrees. The prominent veins of the Union-Carbonate, however, are much more nearly east and west than north and south. It is doubtful whether they can be considered as belonging to the same system as the northwesterly fissures previously described. The northeasterly veins of the Enterprise, Newman, and Rico-Aspen mines, were not recognized in the Union-Carbonate workings at all. If they occur, it is as insignificant stringers of no known importance. In the Fickle Goddess tunnel, however, 682 feet below and to the west of the collar of the Union-Carbonate shaft, several northeasterly veins are cut, but they do not

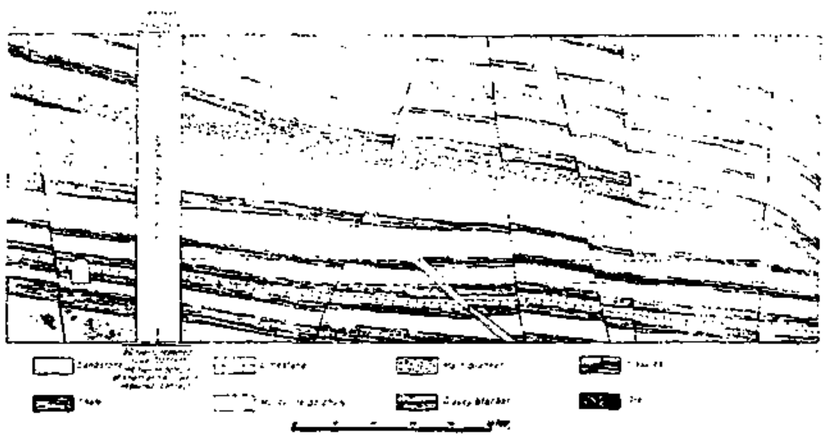


FIG. 59.—Diagrammatic north-south section through the Union-Carbonate mine, illustrating the general structure of the country rock, and showing some of the northwesterly fissures and their relation to the blankets and ore bodies.

resemble those in the Enterprise ground, and carry little save quartz and low-grade pyrite, resembling the northwesterly rather than the northeasterly lodes of the Enterprise.

All of the veins seen are small. They are sometimes composed of quartz carrying a little pyrite or low-grade galena ore. Frequently this quartz is crushed and the vein is often nothing more than a fissure filled with a little crushed country rock, broken quartz, and gouge.

These fissures are usually fault planes, but the displacement is rarely more than a few inches, and is usually normal. Several such faults can be well studied in the crosscut south of the shaft on the 210-foot level, and some of them are indicated in the general section of fig. 59. One vertical vein with a nearly east-west strike, followed for some distance by the main drift on the 190-foot level, is connected with a vertical displacement of the country rock amounting to about 5 feet.

The rocks on the south have been dropped relative to those on the north.

As a rule, the veins in the Union-Carbonate mine carry no workable ore. This is found only in so-called "contacts" near their intersection by the vein fissures. An exception to this statement must be made in the case of one important vein striking N. 65° W., and dipping southwest at 85°, which carried ore to a depth of 30 or 40 feet below the main blanket horizon. Some of the largest and richest bodies of blanket ore occurred above this fissure.

There are several so-called "contacts" in the mine, and as they differ in character, they will be separately described.

The principal ore-bearing blanket passes through the shaft a few feet above the 190-foot level, but is cut by the latter in the southeastern portion of the workings, owing to the general southeasterly dip of the inclosing rocks. In the extreme southern portion of the mine the dip rapidly increases up to 60°, and carries the contact below the 210-foot level. This "contact" is generally 4 or 5 feet in thickness, and rests upon an intrusive sheet of porphyry. In the northern part of the mine it is overlain also by porphyry, but the latter sheet thins out toward the south and east, and the blanket is there overlain by shale. There is considerable irregularity in these relations, however, and it is not uncommon to find the porphyry roof suddenly giving place to shale, or vice versa.

In its less altered condition the blanket is a breccia of somewhat mineralized fragments of shale and porphyry. Where the roof is shale the particles of this rock predominate, even to the exclusion of the porphyry, and the breccia presents the appearance shown in Pl. XXXIV, *B*, which is from a photograph taken on the downward incline on the southeast corner of the 210-foot level. The blanket material at this point consists of angular fragments of gray calcareous shale embedded in a gray clay apparently derived from the disintegration of the shale. Some of these fragments are as much as a foot cube, and in the bottom of the breccia lie in all attitudes. Near the top, however, they remain with their planes of bedding more nearly parallel, and pass with no sharp break into the less-disturbed shales of the roof (Pl. XXXIV, *B*). All of the shale fragments show more or less alteration. Many are bleached nearly white and effervesce freely with dilute acid, whereas the darker fragments contain less calcite. Accompanying the change in color, there has been some replacement of the shale by pyrite, which tends to form in thin sheets parallel to the general laminations of the shale. In some cases, however, a bed of the shale three-quarters of an inch or more in thickness may be observed almost entirely replaced by quartz and pyrite. A characteristic feature of such replacement is the formation of little vug-like cavities partly filled with porous quartz and a resultant porous, friable structure in the whole replacing aggregate. Fig. 60 is a drawing, actual size, of such a replaced band of shale, which a few feet away is only slightly mineralized and preserves its shaly structure. At least a part of the movement which produced the brecciation is later than this mineralization

Above the 190-foot level, where the blanket lies between two sheets of porphyry, and particularly above the more prominent northwest veins, the breccia has been vigorously altered. In some places it is a solid body, 5 feet in thickness, of white quartz and pyrite. Sometimes the latter predominates in crumbling masses containing bunches of galena ore. At other times the quartz has a porous, honeycombed structure containing pyrite and free sulphur. In some such cases the pyrite seems to have been partly dissolved and carried away without deposition of any residual oxides of iron. In others the porous structure has plainly resulted directly from the metasomatic

FIG. 60.—Replacement of a layer of shale by pyrite (black) and spongy quartz, showing characteristic small vugs with outer shells of pyrite and inner lining of quartz crystals.

replacement of fragments of porphyry by quartz and pyrite, with the removal of some of the constituents of the rock. Frequently the blanket quartz is crushed to a white powder—"sugar quartz."

The masses of quartz and low-grade ore just described have resulted from the replacement of a breccia of porphyry and shale by quartz and ore. Where the process has not been so complete, fragments of porphyry may still be detected in the silicified mass. There were at least two steps to the process, the quartz of an earlier generation having been shattered and recemented by later deposition.

However this blanket breccia may have been produced, it has certainly been to some considerable degree a plane of faulting, the beds above it having moved relatively to those below it. But the extent and direction of this movement are wholly unknown. The exact behavior of the vertical veins to this bedding fault could not be ascertained. They apparently do not split up into stringers on approaching the blanket, as do the veins in the Enterprise. They probably pass upward through it, suffering more or less displacement.

Below this principal blanket occur several others of less extent and importance and of different character. These occur in beds of dark shale, particularly in thin beds lying between beds of sandstone or sheets of porphyry. When fully developed these blankets consist of unctuous yellow clay, usually finely banded parallel to the general bedding of the rocks between which it lies. This clay is an alteration product of the shale, and the banding is the result of the original shaly lamination. The various steps in the change from shale to yellow clay may be well seen in the crosscut running south from the shaft on the 210-foot level.

In the vicinity of some of the vertical fissures these clay blankets sometimes contain bunches of ore, usually in the form of impure argentiferous lead carbonates, with occasionally some residual galena. Such an ore body was stoped out from the southern adit tunnel on the 210-foot level. It extended for about 4 feet into the blanket on each side of a vertical fissure striking N. 75° W., and averaged about 3 feet in thickness. In this case footwall and roof were both of porphyry. In the neighborhood of the shaft this shale bed, in part altered to clay and occasionally carrying a little ore, is probably about 50 feet below the main blanket previously described. In the southern part of the workings they come closer together. There has been no faulting along this lower blanket horizon, as shown by the continuity of a dike of porphyry which connects with an overlying intrusive sheet (see fig. 59, p. 343). The shale has been changed to clay in situ by chemical processes, unaided by attrition.

Blankets similar to the last, often of very local extent, were noted at other stratigraphic horizons. Still other blankets are said to exist at 300 and 356 feet below the collar of the shaft, but they could not be reached in 1900.

The ore shipped from the main blanket of the Union-Carbonate mine averaged about $20 per ton as prices were then, and was therefore of low grade compared with the Enterprise or Rico-Aspen ore. It is said to have been 7 feet thick in places, and could be easily mined. It contained about 0.1 ounce of gold, 12 ounces of silver, and a varying amount of lead.

FOREST-PAYROLL MINE.

Situation.—This mine is on the same spur of Dolores Mountain as the Union-Carbonate, but lies on the side toward Allyn Gulch, with its principal adit at about 10,150 feet elevation.

Development.—The principal workings are reached through the Payroll tunnel, about 400 feet in length, running S. 32° W. This tunnel connects with drifts, winzes, and stopes, on two nearly parallel veins, and with irregular workings in two "contacts" or blankets, lying one above the other. There are in addition 5 or 6 other tunnels run into the hillside at higher elevations.

Country rock. This is the Lower Hermosa, consisting of shales, sandstones, and limestones. It is cut by some large dikes of monzonite porphyry, which are connected with intrusive sheets of the same rock.

The lodes. Several fissures are cut by the Payroll tunnel, but none of them have proved economically important. The Magpie vein, intersected about 50 feet from the tunnel mouth, strikes N. 60° W. and dips 80° N. It is little more than a fissured zone in porphyry, containing some gouge.

About 300 feet from the mouth the tunnel cuts the main Forest-Payroll lode, which has been drifted on for 500 or 600 feet. It strikes

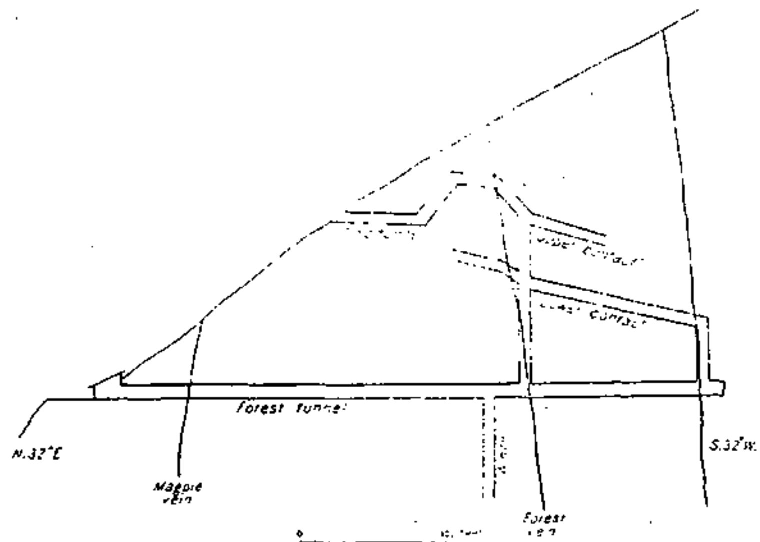


FIG. 61.—Vertical sketch section through the Forest-Payroll mine, along line of main tunnel.

about N. 75° W. and dips about 85° SW. The lode shows a maximum width of about a foot of quartz and low-grade ore, containing much sphalerite. It is usually frozen to the southern wall, but on the northern wall shows some gouge and crushed country rock. Just within this wall is a small parallel vein of white, barren quartz, 3 or 4 inches wide, which appears to be of later age.

A third vein is cut near the breast of the tunnel. This is parallel to the main lode, but is small and has been drifted on for only a few feet.

The ore in the Forest vein is low grade and is found only in small bunches.

The blankets.—The lower of the two blankets ("contacts") lies about 85 feet above the main Forest drift. It is about 5 feet in thickness and dips S. 15° E. at angles from 10 to 15 degrees (fig. 61). It is a breccia of shale mixed with yellow clay and resembles some of the blankets of the Union-Carbonate mine. The roof is shale, while the floor is sandstone. The blanket is not everywhere reduced to breccia and clay for its full thickness, but the softer materials are sometimes separated by harder beds of shale or sandstone which have resisted the transformation undergone by the more susceptible beds and preserve their firmness and continuity. The various nearly vertical fissures encountered in the drifts and crosscuts below pass upward through the blanket and fault it. The maximum throw observed is about 15 feet, due to the Payroll vein. The result of the faulting is to cause the blanket to descend by a series of steps toward the south.

Ore occurs in the blanket in the immediate vicinity of the vertical fissures, but it is small in amount and of low grade. It is sometimes accompanied by crushed white quartz, and is often in the form of impure argentiferous lead carbonate. Some galena occurs, however.

The upper blanket lies from 30 to 50 feet above the lower, the two being generally parallel. It is 5 or 6 feet in thickness, being somewhat larger than the lower one. The roof is shale, rather disturbed and broken, while the floor is sometimes the upper surface of a sheet of porphyry, sometimes a shaly calcareous sandstone.

The blanket material is similar in general appearance to that described in the lower blanket, but it contains considerable amounts of soft, unctuous, black material, which dries to a sooty powder. This substance, which, as shown by chemical analyses (p. 283), is largely oxide of manganese, is frequently in direct association with masses of limestone, the occurrence of which in the blanket is of much interest. In some portions of the workings the limestone occupies the entire depth of the blanket zone, extending from the porphyry or sandstone floor up to the shale roof. It is often fissured and broken, the crevices being filled with the black material above referred to. In other portions the limestone is absent, or occurs in isolated masses of irregular shape, coated with the black substance and embedded in the soft blanket material.

The limestone is finely granular in texture, light buff in color, and is apparently far from being pure calcium carbonate. It is minutely laminated parallel to the general bedding of the inclosing sediments. The black, sooty substance is plainly an alteration product or residue of this limestone. It penetrates the latter irregularly and works inward along the laminæ from the surface most exposed to the attack of the solutions which have effected the transformation. It is apparent that the relation of this limestone to the upper Forest-Payroll blanket is closely analogous to that of the gypsum to the Enterprise and Rico-Aspen blanket.

The upper blanket is faulted by the nearly vertical northwest fissures in the same manner as the lower one. The fissures are sometimes filled with a tough clay gouge, showing evidence of recent movement.

The ore of the upper blanket consists mainly of galena in various stages of alteration to cerussite and anglesite. It occurs in relatively small bodies alongside the vertical fissures. It is not known to occur in the limestone as a direct replacement.

The product of the mine is not known, but can scarcely have exceeded a few thousand dollars.

OTHER MINES.

Mediterranean tunnel.—This is on the south side of Allyn Gulch, at an elevation of about 9,800 feet. It runs in a southerly direction and has a length of about 1,500 feet. The country rock is the Lower Hermosa series of sandstones and shales, cut by several dikes and intruded sheets of monzonite-porphyry.

Owing to the gas in it, this tunnel could not be entered in 1900, but G. W. Tower, who examined the workings in 1898, has recorded the following section, measured northward from the breast of the tunnel out:

69 feet. Massive grits. Strike N. 60° W. Dip SW. 20°.
45 feet. Porphyry dike. Strike N. 60° W. Vertical.
30 feet. Mineralized sediments.
00 foot. Barren fissure. Strike N. 55° E. Vertical.
45 feet. Porphyry. Strike N. 60° W. Vertical.
30 feet. Dark shale. Over this shale is a flat ore body. Strike N. 70° W. Dip SW. 10°.
84 feet. Massive, dark, hardened shale. In places the shale is impregnated with pyrite and chalcopyrite.
12 feet. Porphyry, dipping south and crossing the beds, 9 feet.
18 feet. In sediments to 6-inch vein. Strike E.-W. Vertical. Zinc and lead.
56 feet. Shales, to porphyry. Strike N. 70° E. Vertical.
12 feet. Porphyry. Strike N. 55° W. Vertical.
39 feet. Shales and sandstones. One small vein of quartz. Strike N. 75° W. This turns into the bedding planes of the strata and shows both vertical and horizontal movement.
00 foot. Narrow dike. Strike E.-W. Vertical.
12 feet. Grits, to fissure. Strike N. 60° W. Vertical, 1-inch fissure. The walls are coated with quartz and pyrite. There is also some impregnation of the adjoining country rock.
17 feet. Grits and shales, to fissure. Strike N. 57° W. Dip SW. 50°.
1 foot. Porphyry dike.
17 feet. Shales and sandstones, to mineralized fissure. Strike N. 70° E. Vertical. Eight inches of clay, cubical pyrite, and quartz.
21 feet. Impregnated grits, to fissure. Strike N. 55° W. Vertical.
18 feet. Porphyry.
00 foot. Mineralized fissure. Strike N. 83° W. Vertical. Breccia, containing pyrite and chalcopyrite; 3 feet wide.
32 feet. Sedimentaries.
18 feet. Porphyry dike. Strike N. 78° W. Crosses stratification at low angle.
6 feet. Grits, to vein. Strike N. 53° W. Vertical.

14 feet. Massive pyrite. Strike N. 70° W. Vertical. Crystals, 1 to 2 inches in diameter.
21 feet. Impregnated grits, to porphyry. Strike N. 45° W. Vertical.
30 feet. Porphyry.
60 feet. Sandstones and shales, to fissure. Strike N. 65° W. Quartz.
84 feet. Massive green sandstones, to fissure. Strike E.-W.
12 feet. Sandstones, to pyrite body over porphyry. Strike NE.
65 feet. Porphyry, to northwest fissure, in porphyry.
147 feet. Porphyry.
400 feet. Surface wash and débris to mouth of tunnel.

Sunflower mine.—This is also on the south side of Allyn Gulch, at an elevation of about 10,300 feet. The workings, consisting of a shaft and tunnel, are abandoned as inaccessible. Considerable work is reported to have been expended on a "contact" lying above those described in the Forest-Payroll mine.

Lucy mine.—This mine lies on the northern spur of Dolores Mountain, at an elevation of about 9,500 feet. It was idle in 1900 and was not visited. It has never been productive.

Pro Patria (Scott's) tunnel.—This tunnel enters the northwestern slope of Newman Hill at an elevation of about 9,450 feet. Its course is S. 31° E., and in the summer of 1900 it had reached a length of about 2,000 feet. It is an extensive prospecting venture, being designed to cut the northern extension of the lodes worked in the Enterprise ground and to explore the blanket or blankets in connection with them. The tunnel penetrates Lower Hermosa sediments and intrusive sheets and dikes of porphyry. The shales and sandstones have a general southerly dip. At the face massive beds of sandstone were found dipping to the southwest at an angle of 21°.

Several veins have been cut having general northeasterly or northwesterly courses. But at the level of the tunnel these are small, and carry little save quartz and worthless pyrite.

South Park mine.—The adit of this mine is a tunnel run into the northwest base of Newman Hill from the bed of Silver Creek. As the workings were abandoned in 1900, and the water dammed back in the tunnel, the mine was not entered. For a distance of about 500 feet, in monzonite-porphyry, the tunnel follows a fissure striking a little south of east, which Cross and Spencer have designated the South Park fault. Apparently, no ore was found in connection with this fault fissure. About 350 feet south of it, however, a nearly parallel vein is said to have made a small body of good ore at its intersection with a bed of dark shale about 7 feet in thickness. The ore is reported to have been about 12 feet wide. The vein itself also carried ore for a distance of about 20 feet above and below the shale horizon. The strike of the beds, which are low in the Lower Hermosa formation, is about N. 30° W., and the dip is southwesterly at about 25°.

The occurrence of this blanket ore in the South Park mine is of interest, since it is found below the large intrusive sheet of porphyry that sweeps around the base of Newman Hill just east of Rico, and forms the country rock of the Skeptical shaft. The other ore-bearing horizons, however, such as the Enterprise, Union-Carbonate, Forest-Payroll, and New Year blankets are all above this sheet.

Hibernia tunnel.—This also enters Newman Hill from Silver Creek, about 600 feet west of the South Park. For about 350 feet the tunnel runs S. 12° E. It then turns and holds a somewhat crooked course to the east. Like the South Park, the tunnel enters in monzonite-porphyry and continues in this rock until a point is reached about 420 feet east of the turn, where the base of the sheet is passed through. At this place the porphyry sheet shows a westerly dip of about 15°. It is underlain by thin-bedded shales, sandstones, and limestones belonging to the lowest portion of the Lower Hermosa. A seam of gouge between the porphyry and the underlying sediments indicates some movement along this plane. About 110 feet farther east a fault, with a general north-and-south course, crosses the drift and brings porphyry on the east against Hermosa sediments on the west. This porphyry is apparently the same sheet just described, which is here faulted down on the east. Toward the breast of the tunnel the general southwesterly dip again carries the base of the porphyry up, and at the breast a bed of black shale about 1 foot thick underlies the porphyry, and is itself underlain by a bed of dark limestone, of which only the upper foot of thickness is exposed. The shale dips 12°, a little west of south. A little seam of fluorite occurs between the shale and the limestone.

The Hibernia was originally run to intersect the northerly continuations of the Enterprise veins. If its initial course had been maintained, however, it is doubtful whether it would ever have emerged from the massive sheet of porphyry. But by turning eastward it was enabled to come out beneath the porphyry, which here appears to dip a little west of south. Whether the bed of shale beneath the porphyry will be found ore bearing is unknown. The position of this shale between massive limestone and thick overlying porphyry is certainly favorable to its being locally brecciated and filled or replaced by ore in the neighborhood of vertical fissures. Assays of the almost undisturbed shale in the breast are said to yield $6 in gold per ton.

Numerous small veinlets are cut in the easterly crosscut of the Hibernia tunnel. They are of no importance and generally have a northwesterly course.

Onamo tunnel.—This is a crosscut, 1,400 feet in length, which enters the northwest slope of Newman Hill about 700 feet east of the Skeptical shaft at an altitude of about 9,350 feet. Its course is about

S. 23° E. *It belongs to the Enterprise Company and was planned to connect with workings from the Laura shaft, but was never completed.*

Isabella shaft and Wakeman tunnel.—The shaft was sunk east of the Enterprise adit at an elevation of 9,650 feet. It is reported that at a depth of 80 feet the Enterprise blanket was encountered, dipping southwest at an angle of 30°. The shaft was then abandoned, and an attempt was made to reach this blanket by a tunnel driven into the hill about 250 feet above the Group tunnel. This tunnel, however, has revealed the blanket dipping easterly, there being apparently a local syncline between the tunnel and the shaft. In an attempt to get around this depression without cutting through the shale roof of the blanket, and thereby letting in the surface waters, the tunnel has become exceedingly tortuous, and no connection has yet been made with the Isabella shaft. A little ore has been found in this portion of the blanket, but it is of too low grade to ship.

MINES OF HORSE CREEK.

PUZZLE MINE.

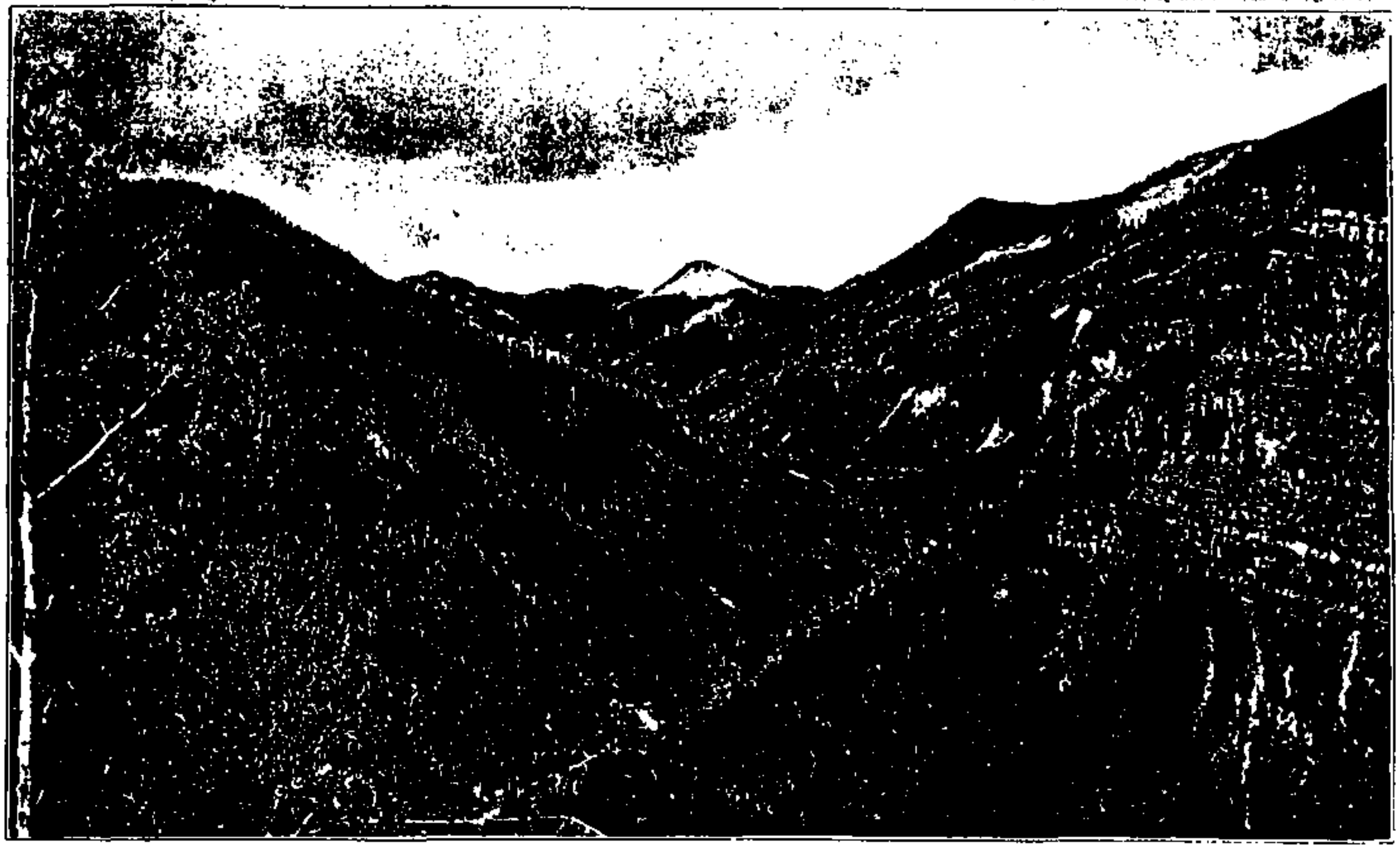
This appropriately named property occurs on the south side of Horse Creek, a little more than three-quarters of a mile from its mouth. As the geological map shows, it is in the lower part of the large landslide area forming the north slope of Darling Ridge.

The Puzzle mine was discovered about the year 1879 and during the first few years of operation produced nearly $300,000. The ore was a partly oxidized silver ore, frequently carrying from 600 to 1,800 ounces per ton and containing over 50 per cent of silica. None of this ore could be seen at the time of visit, but it was probably argentite, largely changed to native silver. C. W. Purington states in his unpublished notes that embolite, the chlor-bromide of silver, was also present. The ore was treated by barrel amalgamation in works situated about 1,000 feet south of the mouth of Horse Gulch. These have since been torn down.

After a few years the Puzzle ore body was worked out, and in 1900 the workings had long been abandoned and could not be entered. Many attempts have been made to find a continuation of the Puzzle ore body, but none of these have thus far been successful.

The country rock of the Puzzle (and Puzzle extension) consists of sandstones, shales, and limestones, belonging without much doubt to the medial division of the Hermosa. These are cut by one or more dikes of monzonite-porphyry.

These rocks, however, are not in place. They form a mass which has slipped for an unknown distance down the slope from the south, burying the former bed of Horse Creek and forcing the latter to swing



VIEW UP HORSE CREEK FROM [illegible] IN THE DISTANCE around the obstruction and cut a new bed to the north of the old one. This change in the course of the stream is indicated in the map (Pl. XLI).

A shaft 40 feet deep, sunk in the little swale which separates the Puzzle knoll from the main hill slope, passed through the landslide material and encountered buried stream gravels containing bits of wood. Gravels were seen in 1900 at the bottom of a winze sunk 20 feet below the Hess and Garren tunnel, about 100 feet from its mouth. They consist of well-rounded pebbles and bowlders of various rocks, of all sizes up to 10 inches in diameter. Mingled with these is much fine gravel and clay. This gravel rests upon a worn and irregular surface of black limestone, which in one place is cut by a dike of porphyry.

It is impossible to be certain whether the gravels just described are identical with those underlying the Puzzle ore and found in the bottom of the old shaft above referred to. It is highly probable that successive landslides took place, compelling the stream to change its course more than once. After such a slide the stream would be dammed, and would deposit silt and gravel above the obstruction. This deposit would in turn be buried by the mass of rock slipping or creeping down the slope from the direction of Darling Ridge.

The mode of occurrence of the Puzzle ore can at present be only imperfectly ascertained through conversation with those who formerly worked in the mine. It was an irregular replacement of the upper portion of a bed of dark fossiliferous limestone. On the north it was limited by the present stream bed, on the east by a fracture plane filled with gouge, and on the west was cut off by a mass of buried stream gravels. The ore-bearing limestone stratum is reported to have been greatly fractured and elevated toward the south by a succession of small step faults until finally cut off by a soft mass of crushed rock and gouge. It is not known what rock directly overlay the ore, although in some places broken rock and gouge is reported. Below the foot-wall limestone are the stream gravels of the old bed of Horse Creek.

The Hess and Garren tunnel, starting from the bed of Horse Creek, in the Puzzle Extension claim, just west of the Puzzle workings, runs in a direction S. 10° E. for about 325 feet. The rocks encountered are sandstones, shales, and limestones, all greatly disturbed. Bedding faults and cross fractures filled with soft clay gouge are numerous, and in many places the beds are reduced to a chaotic mass of fragments mingled with clay. At one point, perhaps 200 feet from the mouth, gravels were noted mixed with clay and angular rock débris. At the breast is a massive bed of black limestone overlain by shales and sandstones, all dipping north at 15°. Above the limestone is a prominent bedding fault filled with crushed shale and gouge. Other similar but smaller fault fissures occur in the overlying shales and sandstones. There can be no doubt that the entire tunnel is in landslide material, derived mainly from the Middle Hermosa.

A shaft sunk some years ago by J. O. Campbell on the Puzzle Extension ground encountered, at a depth of 60 feet, a bed of light ashy material about 12 feet thick. This layer consists partly of a pale sky-blue vitreous mineral, which was determined by Mr. C. W. Purington, through blowpipe tests, to be allophane, a hydrous silicate of alumina. The origin and association of the mineral at this occurrence could not be ascertained. Specimens show the allophane mixed with earthy material, the structure of the whole suggesting an alteration product of some unknown brecciated material.

M. A. C. MINE.

This property, lying on the hill slope, about 200 feet above the Puzzle mine, embraces two tunnels, a vertical shaft and an inclined shaft formerly known as the Hoosier Girl. The tunnels are prospects, run to find the original ore body from which that of the Puzzle was derived. The lower tunnel, at an elevation of 9,600 feet, runs S. 2° W. and is about 400 feet in length. It is all in limestone, which is so shattered as to require timbering throughout. The limestone, belonging to the middle division of the Hermosa formation, is irregularly fractured into large blocks separated by seams of unctuous clay gouge. It is all landslide material and not in place. It has slipped for an unknown distance down the slope of the hill, and the beds themselves have slid over each other and have been at the same time irregularly broken.

The upper tunnel is 50 feet higher than the lower and is about 550 feet in length. For 175 feet it runs S. 4° E. in thick-bedded dark limestone with a general northerly dip of 15°. This limestone is shattered into great irregular blocks separated by gaping crevices or by fissures a foot or more in width filled with yellow clay. Although the fragments are often confusedly jumbled, yet the original bedding is not entirely obliterated.

The tunnel then turns eastward and penetrates highly disturbed sandstone, shale, and limestone, and a little intrusive porphyry for a distance of nearly 300 feet.

About 275 feet from its mouth the upper tunnel connects with an incline leading to a vertical shaft. These workings show fine-grained sandstones and shales above the limestone in the tunnel. A little ore, chiefly copper carbonates in a calcite gangue, occurs, mixed with clay and breccia between the limestone and overlying sandstone. It varies from a few inches to a foot in thickness, but is of small lateral extent, being cut off by slip planes.

Both tunnels cut several shattered quartz veins, apparently of no value. One in the upper tunnel is 5 or 6 feet wide. No rock was seen in either tunnel which could be looked upon as being in place.

The old Hoosier Girl inclined shaft lies about 100 yards southeast of the lower M. A. C. tunnel. It is on a large vein apparently striking N. 75° W., but poorly exposed. The dip is to the south for the first 20 feet at an angle of 22°, and then increasing to 50°. The vein consists of barren, coarsely crystalline radial quartz. The centers from which the quartz has crystallized are often rhombs of calcite showing curiously dull and pitted surfaces, as if they had been attacked by some solvent before the quartz was deposited.

MOHAWK MINE.

This is in Mohawk Gulch, on the north side of Horse Creek, at an elevation of about 9,750 feet. The vein, having a general northwest-southeast strike, was worked through a crosscut tunnel, now caved in. The dump shows monzonite-porphyry and shale, with some pyrite and sphalerite. Both walls of the vein are said to be porphyry, probably a dike. The material on the dump shows that the porphyry in the vicinity of the fissure has been altered to a skeleton of cryptocrystalline quartz containing fine particles of pyrite. The larger feldspar crystals of the monzonite-porphyry have been removed, giving the siliceous alteration product a spongy texture, which reproduces to a certain extent the original porphyritic structure of the rock.

About 20 tons of ore, containing 40 ounces of silver per ton, is said to have been obtained from the mine in 1886.

The geological map of Cross and Spencer (Pl. XLI) shows a fault passing through the Mohawk mine. It is not known what influence this dislocation has upon the vein.

GREAT WESTERN MINE.

This is a prospecting tunnel about 2,000 feet west of the Puzzle mine, and on the north side of Horse Creek. The tunnel has a northwest course and is over 400 feet in length, the face being inaccessible owing to caving. It penetrates shales, limestones, and sandstones, probably belonging to the middle division of the Hermosa formation, with an intercalated intrusive sheet of porphyry. The general dip of these rocks is to the north at about 15°, and they are apparently in place, although the tunnel for 125 feet from its mouth passes through surface wash and slide. About 250 feet from its mouth the tunnel exposes a blanket about 6 inches thick, lying between shaly limestone below and shaly sandstone above. This layer of brecciated material is apparently not of great extent, and practically dies out in a distance of 25 feet to the west of the tunnel, where the shaly sandstone rests upon the limestone with but slight evidence of disturbance.

A second and stratigraphically higher blanket appears in the roof of the tunnel, about 300 feet from the mouth, and dips down toward the breast. This is a soft, dark breccia consisting of crushed shale, sandstone, and limestone, lying between two beds of limestone. In places it is at least 6 feet in thickness and contains within it a sheet of porphyry 3 feet thick, which has been altered to a soft gray clay containing much fine pyrite.

LACKAWANNA AND OTHER MINES.

West of the Great Western tunnel and scattered along Horse Creek are several small mines which were formerly worked and from some of which a few tons of ore were taken prior to 1887. They include the Lackawanna, Puzzler, Flying Fish, Roderick Dhu, Christina, Belzora, San Juan, and Golden 1900 (formerly the Sunnyside). These are all abandoned and no longer accessible. Most of them are on veins striking about N. 55° W., the Belzora and Christina being supposed to be on the same fissure.

High up on the north side of Darling Ridge, at an elevation of 10,700 feet, is the Magnet mine, in which a little work has been done upon a body of magnetite. This magnetite occurs as a replacement of limestone belonging to the Middle Hermosa, and has an average thickness of about 5 feet. The beds in which it lies strike southeast and northwest and dip northeast at about 45°. But the entire deposit is within the large Horse Creek landslide area and is probably not in place. That the ore is limited and cut off by faults, is shown even by the present very superficial workings.

The limestone which forms the hanging wall is cherty, but that upon which the ore rests is a soft white granular limestone, penetrated irregularly by streaks of magnetite and malachite.

The ore, which in its upper part is slightly oxidized, contains a little chalcopyrite. The best contains about 65 per cent of iron, with half an ounce of silver and a tenth of an ounce of gold per ton. A little was being mined in 1900 and sold to the smelter in Durango for use as a flux. But as the smelter allowed only $4 or $5 a ton for the iron and the cost of transportation amounted to $4 per ton, the operation could scarcely be very profitable.

The Uncle Remus mine, situated at an elevation of 11,350 feet at the junction of Darling Ridge with Expectation Mountain, was formerly worked through a shaft and tunnel. It is on an irregular vein in monzonite-porphyry, from which a little gold ore containing tellurium has been extracted. Chemical tests by Dr. H. N. Stokes show that a little molybdenum occurs in the ore. The workings were caved and abandoned in 1900.

There are several prospects on the South Fork of Horse Creek, including the Hand-Out, upon some of which considerable work has been done; but they were all abandoned and inaccessible in 1900, and no information concerning them was obtainable.

On the West or Middle Fork considerable tunneling has been accomplished on the Palmetto group, but no ore has been produced. There are various other small prospects in the vicinity, one of which—the Marriage Stake—is on a nearly vertical fissure in porphyry, striking nearly east and west. The fissure contains no vein quartz, but the porphyry for a width of 5 or 6 feet is silicified and impregnated with pyrite in the manner described on the Mohawk prospect.

JOHNNY BULL MINE.

This mine, situated in the saddle between Calico Peak and Johnny Bull Mountain, was opened in 1879, and in the course of one or two years produced about $100,000. The ore then became exhausted, and the mine has been abandoned for many years. The ore is said to have occurred in a "chimney," roughly circular in plan, and 10 or 15 feet in diameter. It was mined through a vertical shaft 123 feet in depth. This shaft is now caved in, and only a crater-like pit on the surface marks the site of the former ore body. A tunnel 190 feet in length was run in from the west side of the ridge in 1882 to connect with the shaft. The connection was effected, but the ore gave out at this point.

The country rock of the Johnny Bull consists of fine-grained sandstones and shaly limestones belonging to the Dolores formation, cut by sheets and dikes of monzonite-porphyry. As seen in the crater-like depression above the old workings, the ore body was inclosed in a very fine-grained, nearly white sandstone, which is minutely impregnated with pyrite and traversed by small, irregular dikes of porphyry. Close to the ore this sandstone contains abundant pyrite, is traversed by irregular streaks which differ from the rest of the rock in containing numerous spots of kaolin, and is often strongly silicified. The gangue of the ore is composed of cryptocrystalline quartz, full of minute vugs, which has resulted from the complete silicification of the fine-grained sandstone. This silicification extends irregularly into the inclosing country rock, particularly along bedding planes.

Below the ore body a vein was encountered in the crosscut tunnel already mentioned. This vein strikes N. 25° W. and dips northeast, and as shown by the dislocation of beds of sandstone and a sheet of porphyry which it cuts, corresponds to a small normal fault. This fissure is less than a foot wide and contains crushed rock, gouge, and a little ore. The Johnny Bull ore body was apparently deposited from this fissure through silicification and replacement of certain beds favorable to such metasomatic action. The localization of the deposit as a "chimney" appears to have been due to the existence of one or more cross fractures.

The ore of the Johnny Bull consisted of enargite, pyrite, black oxide of copper, free gold, and probably other minerals. It was of high grade, both in gold and silver. Chemical tests made by Dr. H. N. Stokes showed that some of the ore contained tellurium and traces of bismuth.

GOLD ANCHOR MINE.

This is entered by a tunnel about 700 feet in length, which runs from Bull Basin in a direction N. 65° W., and passes under the Johnny Bull workings. The tunnel passes through conglomeratic white sandstone, fine-grained sandstones, and shaly limestones belonging to the Dolores formation.[1] These beds strike N. 15° E. and dip westerly at about 25°. They are cut by several dikes of porphyry, which in some cases contain phenocrysts of kaolinized feldspar up to 2 inches in length, and by one clastic dike 8 inches wide, filled with firmly consolidated fragments of sandstone and grit, with some quartz pebbles.

About 450 feet from its mouth the tunnel cuts the Anchor vein, striking north and south, and dipping east at about 70°. Where seen, this vein is chiefly a soft gouge, showing evident signs of recent movement. It shows a porphyry dike or sheet on the hanging wall. Some specimens of ore from this vein show metasomatic replacement of fine-grained light sandstone by pyrite and tetrahedrite. The process of ore deposition is closely similar to that in the Johnny Bull.

Nearly 600 feet from the mouth the tunnel intersects a fissure which is supposed to be the Johnny Bull vein. It strikes about N. 50° E. and dips southeast 50°. At the tunnel it is a mere seam of soft gouge, less than 5 inches wide, carrying a little pyrite and traversing fine-grained sandstone. This fissure was drifted on for about 60 feet to the northeast, where it opened into a small "chamber" or stock of pyrite about 10 feet in diameter. Some of this pyrite upon assay afforded over 90 ounces of gold, and it was stoped up for 45 feet. But as a whole the ore did not pay the cost of its extraction. A little tetrahedrite was associated with the pyrite. The ore body, like that of the Johnny Bull nearly directly above it, was formed by local replacement of fine-grained sandstone and shale adjacent to the fissure. It may well be doubted whether this fissure is the same as that of the Johnny Bull, as the two (as nearly as could be determined by the short exposures available) are divergent in dip and strike.

OTHER PROSPECTS IN BULL BASIN.

The Albion (formerly the Victoria) was formerly worked through two shallow shafts and produced a small quantity of pyrite and tetrahedrite ore from a small irregular fissure.

---

[1] It is of interest to note that the red color so characteristic of the Dolores formation of the Juratrias on surface exposures disappears underground (at least in this region) and the beds become nearly white.

The Caledonia (formerly the Rico) is supposed to be on the same vein as the Albion. It was opened by a shaft and tunnel and is reported to have yielded a little "black copper" ore. The vein as seen in the shaft strikes N. 40° W. and dips northeast at 85°. It is composed of solid quartz up to 16 inches wide carrying sphalerite and pyrite.

The Utah claim, on the north side of the lower part of the basin, is on a large vein of barren white quartz striking N. 55° W. and dipping 50° to the northeast. The country rock is pebbly sandstone of the Dolores formation. Considerable drifting has been done on this vein, which is sometimes over 3 feet wide. The quartz is fractured and crushed, and shows no mineralization beyond an occasional speck of pyrite.

MINES OF THE EASTERN SLOPE OF EXPECTATION MOUNTAIN.

N. A. COWDREY MINE.

This is situated on Sulphur Creek at an elevation of 8,850 feet. The workings consist of a tunnel something over 500 feet in length, running S. 60° W., and some stopes in a blanket. The tunnel follows an irregular bunchy lode, in massive fine-grained sandstone belonging to the Lower Hermosa, and dipping S. 30° W. at an angle of 20°. Low-grade ore, consisting of pyrite, galena, and sphalerite in a quartz gangue, occurs in the larger portions of the lode, which often splits into irregular and discontinuous stringers. The general dip of the lode appears to be southeasterly, at a high angle.

About 500 feet from the mouth the tunnel cuts a blanket, which is composed of a bed of black shale about 18 inches thick, resting on massive sandstone. Above the shale is about 3 inches of limestone, then 18 inches more shale, and then massive sandstone. Near the lode the lower shale is crushed and veined with quartz. The ore occurs near the bottom of the bed, resting on the sandstone. It consists chiefly of galena and sphalerite, and is of low grade. From 100 to 200 tons have been extracted, but the mine is now idle.

The main lode appears to pass upward through the blanket, although its identity is obscured within the mineralized shales.

TOMALE MINE.

The abandoned workings of this mine are also on Sulphur Creek, about 50 feet higher than the N. A. Cowdrey. The adit tunnel follows an ore-bearing stringer striking S. 55° W., and dipping northwest at an angle of about 75°. The stringer is usually about an inch wide and carries galena, sphalerite, chalcopyrite, and pyrite, with very little quartz. The country rock is fine-grained massive sandstone of the Lower Hermosa, which is traversed by several other stringers generally parallel to the one followed.

About 60 feet from the mouth of the tunnel the stringer is cut off by a fault which strikes N. 50° W. and dips 60° NE. This fissure carries white quartz and some pyrite, the whole being somewhat crushed, and accompanied by gouge.

A crosscut of 18 feet to the northwest along this fault shows that the country rock is traversed by many small veins, generally parallel to the one followed in the tunnel. Some of these carry ore. Others, like the fissure faulting them, contain only quartz and pyrite. At the end of the crosscut, a stringer about 3 inches wide, of solid galena, sphalerite, and chalcopyrite, was encountered in the southwest side of the crosscut, cut off sharply toward the northeast by the fault. This stringer was then drifted on as the main vein, but it is by no means certain that it is the same as the ore originally followed northeast of the fault. This lead was drifted on for 150 feet, but it maintained its character as a small, tight-branching stringer, and the prospect was finally abandoned.

ARGONAUT MINE.

This mine is also on Sulphur Creek and is entered through two tunnels a few yards upstream from the Tomale adit. These tunnels are separated by a vertical distance of about 50 feet, both entering in the same sheet of porphyry. In the lower level a crosscut of 125 feet gives access to the lode, which strikes N. 40° E. and dips northwest at an angle of 60°. About 150 feet of drifting on the vein was accessible on this level at the time of visit. The lode varies in width up to a maximum of 1 foot. It frequently splits up into a stringer lead which is too lean to work. The ore consists of galena, sphalerite, chalcopyrite, and pyrite, in a gangue of unusually spongy quartz, full of minute vugs. There is usually a gouge on both foot and hanging walls.

The vein has been stoped through to the upper tunnel, which enters in porphyry, but finally cuts through the upper surface of the sheet into overlying shales and fine-grained massive sandstones and limestone belonging to the Lower Hermosa. These beds dip S. 15° E., at an angle of 40°. The unusual steepness of this dip is probably due to local irregularity consequent upon the intrusion of the porphyry.

The lode in this level preserves the general character already noted. The ore, however, is sometimes nearly free from quartz, and the existence of sheeting and minor veining of the country rock alongside the main fissure is better shown.

It is reported that the ore did not extend up into the shale which immediately overlies the sheet of porphyry. At the time of visit the top of the old stopes was not accessible, but G. W. Tower records in his notes that the overlying shales are brecciated and the limestone silicified, but that no ore was deposited.

No work has been done on this property for years.

BANCROFT MINE.

This lies about 1,500 feet north of the Argonaut, and, like most of the properties in the vicinity, is at present little more than an abandoned prospect. It was proposed in 1900, however, to reopen it for zinc ore. It has been opened by a tunnel and shaft. The tunnel follows a vein striking N. 50° E. and dipping northwest at 75°. The country rock is Lower Hermosa sandstone, dipping south at an angle of 15°. A second parallel vein lies about 12 feet to the northwest. Resting directly upon the sandstone is a layer of soft shale breccia and yellow clay from 2 to 3 feet thick, overlain by shale. The northwest vein is apparently cut off sharply at the base of this breccia. The other vein, the one followed by the main tunnel, loses its vein character upon reaching the breccia, and the latter shows a little ore, while the underlying sandstone is also slightly mineralized. It is reported that some ore was stoped from this blanket, extending to a distance of 30 feet from the fissure.

Most of the old workings are no longer accessible, and although some highly sphaleritic ore was seen on the dump, it was not seen in place except in small amounts in the northwest vein. The same sheet of porphyry cut in the Argonaut workings was apparently encountered in the Bancroft shaft and in the abandoned St. Louis shaft, a little higher up the hill.

SILVER SWAN MINE.

The adit of this mine is a tunnel some 900 feet in length, entering the mountain about 500 feet south of Sulphur Creek, and near the level of the Dolores River. This tunnel runs S. 80° E. in Lower Hermosa sandstones, shales, and limestones. It cuts several small veins of no economic importance as far as known. Near the breast of the tunnel a raise of 60 feet connects with a short upper level. Here a small and irregular vein followed in the lower level becomes much larger, striking N. 80° E. and dipping north at 70°. At the west breast of this upper drift the vein shows a foot of ore next the hanging wall, consisting of galena, sphalerite, chalcopyrite, and pyrite, with about 3 feet of sheeted sandstone and ore-bearing stringers on the foot wall.

Another rise of 12 feet gives access to a higher level, which at its western end cuts a well-marked blanket. This consists in its lower part of about 6 inches of soft gray clay or gouge, above which is an unknown thickness of black shale which has been shattered and crushed to a tough clayey mass. The whole "contact," which undoubtedly represents a pronounced bedding fault, rests upon sandstone dipping 10° or 12° to the southwest.

The main lode is said to spread out to a width of 20 feet and to carry galena ore immediately below the gray gouge. The veins are certainly cut off squarely at this horizon, but the development is not yet sufficient to determine the precise mode of occurrence and extent of the ore bodies.

The ore so far found is of low grade, with its value chiefly in silver. It has not yet been produced on a commercial scale.

LITTLE MAGGIE GROUP.

This is a group of prospects on the west bank of the Dolores River, about 800 feet north of Sulphur Creek, and includes the Little Maggie, Birchard, and Hardscrabble claims. The several tunnels and drifts in Lower Hermosa beds expose a blanket closely resembling that of Newman Hill. It rests upon a bed of limestone and is overlain by dark shale. It consists chiefly of a shale breccia and contains a few small bunches of ore. The limestone and shales beneath this blanket are traversed by numerous small stringers of white quartz, but no work has been done to determine whether these indicate the presence of a vein or veins beneath. Various incipient or local blanket breccias were noted in the dark shales at different stratigraphic horizons.

IRONCLAD MINE.

This lies about 500 feet north of the Little Maggie group, in Lower Hermosa beds, striking northwest and dipping southeast at 15°. The tunnels of this mine were caved in at the time of visit. The main vein is reported by G. W. Tower to have a course of N. 55° E. This vein is said to have yielded about 300 tons of ore, containing 30 ounces of silver per ton and 6 per cent of copper, from a pocket encountered at its intersection with a fissure running N. 30° W.

WHIM MINE.

This property, no longer accessible, was opened by four tunnels about 200 feet north of the Ironclad. Tower states that a vein striking N. 50° W. is slightly faulted by a vein trending N. 20° E., and that both carry galena in a gangue of quartz and calcite.

LITTLE LEONARD MINE.

This prospect is situated between Iron Draw and Sulphur Creek, at an altitude of about 9,800 feet. There are several tunnels, of which the lowest only was accessible at the time of visit. This is about 300 feet in length and cuts a number of northwest-southeast fissures in monzonite. These are unusually numerous and have rather flat southwesterly dips ranging from 10° to 40°. They frequently contain nothing but gouge, although there is sometimes a little crushed quartz present. No ore was seen.

MONTEZUMA MINE.

This is opened by two tunnels about 150 feet above the settlement known as Piedmont, which lies north of and just across the river from Rico.

The lower tunnel is about 300 feet in length and has a course of N. 55° W. for about half the distance and then turns N. 70° W. It follows a tight and irregular vein which dips southwest about 70°. For a distance of nearly 250 feet from the mouth of the tunnel the country rock is quartzite, referred doubtfully to the Devonian. Beyond this appear limestone, sandstone, and shales, belonging to the Lower Hermosa, and dipping S. 40° W. at an angle of 15°. Associated with these beds is some intrusive porphyry, apparently a sheet connected with the large eruptive mass which extends up the spur between Aztec Gulch and Iron Draw.

At the point where the tunnel emerges from the Devonian quartzite it cuts a very irregular blanket, consisting of crushed and pulverized rock, gouge, and ore. This material rests partly on the quartzite and partly upon monzonite-porphyry. It is overlain by shales and sandstone. It is apparently a bedding fault along a bed of limestone, which has been broken up and partly replaced by ore. The latter consists chiefly of pyrite and chalcopyrite in a gangue of quartz and chlorite. A little galena has also been found.

This blanket ore is directly connected with the main vein, which continues up through the overlying sediments, and which, as far as could be determined, is not a plane of perceptible faulting. The porphyry and quartzite that underlie the breccia are impregnated with pyrite. Part of the quartzite shows in addition intense metamorphism of a kind not usually associated with ordinary ore deposition. In its initial stages this alteration consists of the development of green hornblende in the interstices of the quartzite. But where the process has been complete the quartzite is replaced by a coarsely crystalline aggregate of pale-green hornblende, pyroxene, and epidote. In other places the metamorphosed rock consists of coarsely crystalline pyrite, chlorite, quartz, and dolomite. This metamorphism is evidently of the same origin as that so noticeable in the Atlantic Cable, Shamrock, and Smuggler claims, and generally prevalent in the Devonian rocks just north of Rico.

The upper tunnel follows a small vein lying a little north of and generally parallel to that followed in the lower tunnel about 25 feet below. On the north side of this tunnel a flat deposit of iron pyrite, in a matrix consisting chiefly of chlorite and ranging in thickness from 1 to 2 feet, extends to an unknown distance from the vein. It dips southward at a small angle. It is a replacement along a bedding plane in the quartzite, which shows a somewhat similar alteration to that already described.

The Smelter fault, as described by Cross and Spencer, must pass through or very near the upper tunnel of the Montezuma, but the workings themselves fail to reveal its presence.

CALUMET MINE.

This prospect is of interest through being on a vertical fissure, which is probably a branch of the Last Chance fault.[1] It is opened by a tunnel 500 feet in length, which enters about 1,000 feet south of Aztec Gulch and about 100 feet above the Dolores River. The vein is 4 or 5 feet in width, but without regular walls. It is filled with quartz, usually much crushed, containing bunches of pyrite.

The country rock near the mouth of the tunnel is fine-grained sandstone, changing near the breast to shale and intrusive porphyry. It is all more or less impregnated with pyrite and chalcopyrite, and the porphyry in particular is traversed by numerous minute stringers of quartz and pyrite and decomposed to a soft gray mass. Stringers containing quartz and pyrite and striking northwest and southeast are very numerous.

AZTEC MINE.

This mine, one of the first to be opened in the district, is situated in Aztec Gulch at an elevation of about 9,600 feet. It has been worked very irregularly for various short periods since 1879 and has made some small shipments of ore. About 24 tons were produced in 1895, which carried from \$2 to \$3 in gold and 17 ounces of silver per ton and 11 per cent of lead.

The developments are confined to some tunnels and small stopes on the Aztec lode. This strikes about N. 70° W. and dips north at from 80° to 85°. The country rock consists of shales, sandstones, and shaly limestones of the Lower Hermosa formation.

As exposed in the upper tunnel, the vein consists of white banded quartz, 3 feet in width, the banding being due to thin films of partly silicified gouge or shale inclosed in the quartz. This quartz is practically barren, containing only a little pyrite. On the footwall is a breccia of shale and shaly limestone about 2 feet wide, which passes without definite wall or gouge into the undisturbed shales and limestones forming the country rock (fig. 62). Both breccia and country rock are mineralized, chiefly with pyrite, to a distance of at least 5 feet from the vein. Much of this mineralization is a metasomatic replacement of calcareous shale bands similar to that described (fig. 60, p. 345) in the Union-Carbonate mine.

[1] Cross and Spencer, loc. cit., p. 129.

On the hanging wall of the vein is a somewhat similar breccia, the width of which is not certainly known; but it is at least 5 feet. This breccia consists chiefly of shale fragments, often cemented by white quartz, and sometimes by ore.

The geological work of Cross and Spencer has shown that the Nellie Bly fault, which passes over the point of Nigger Baby Hill, probably extends through Aztec Gulch. The character of the Aztec vein cer-

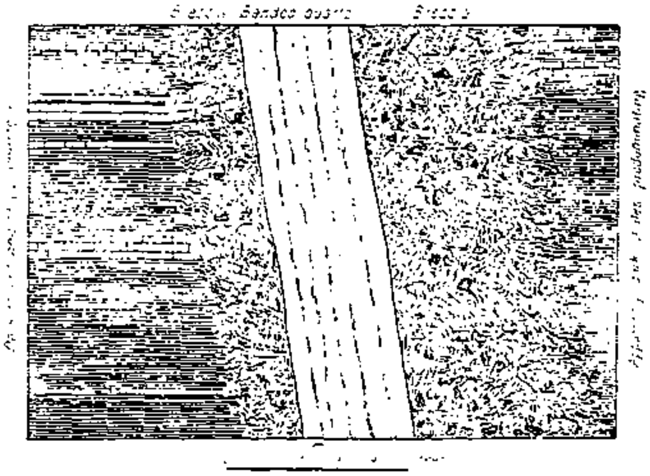


Fig. 62.—Cross section of the Aztec lode.

tainty indicates that considerable differential movement has taken place along this fissure. The development of the mine, however, is not sufficiently extensive to determine the throw of the fault at this point.

The Columbia claim, also an early location, is on the same vein as the Aztec, and is situated a few hundred feet lower down the gulch. It has not been worked for years.

SAMBO MINE.

This mine lies on the northeast slope of Expectation Mountain, between Horse Creek and Aztec Gulch. The principal adit is a tunnel entering the hill at an altitude of about 9,250 feet. The main workings are shown in the sketch plan of fig. 63. They are in shales and sandstones belonging to the Lower Hermosa.

Several veins are cut by the tunnel, as shown in fig. 63, but they have not proved of any importance. The main Sambo vein is usually from 3 to 4 feet wide, composed of solid mottled quartz carrying a little pyrite. The mottling is due to numerous silicified fragments of shale included in the vein. The vein strikes N. 75° W. and dips northward at about 65°. It occupies a fault of at least 4 or 5 feet throw. But whether normal or not, could not be determined. This vein is itself of no value, but immediately above the top of the drift it is con-

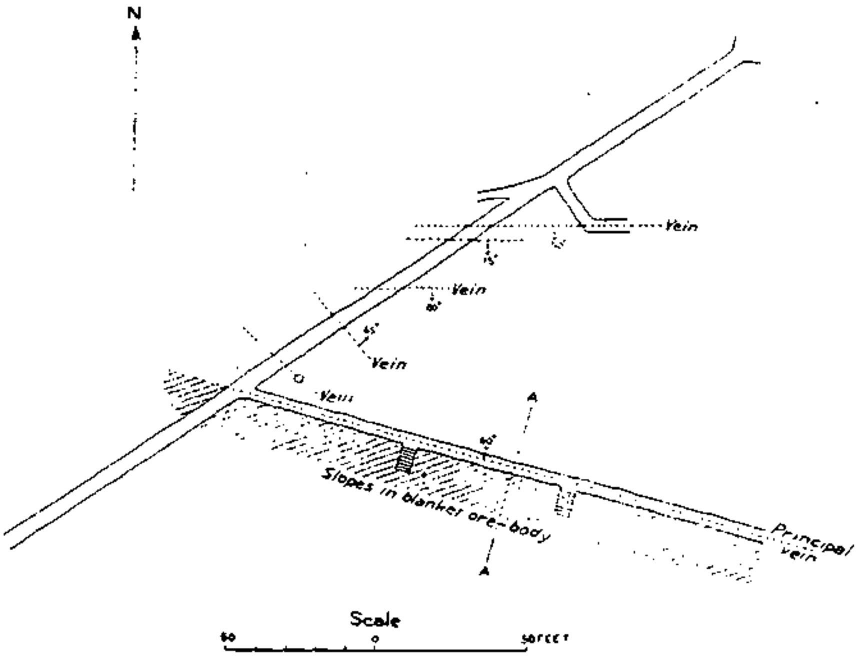


FIG. 63.—Sketch plan of the Sambo mine.

nected with a blanket of quartz and ore inclosed in shales, while a

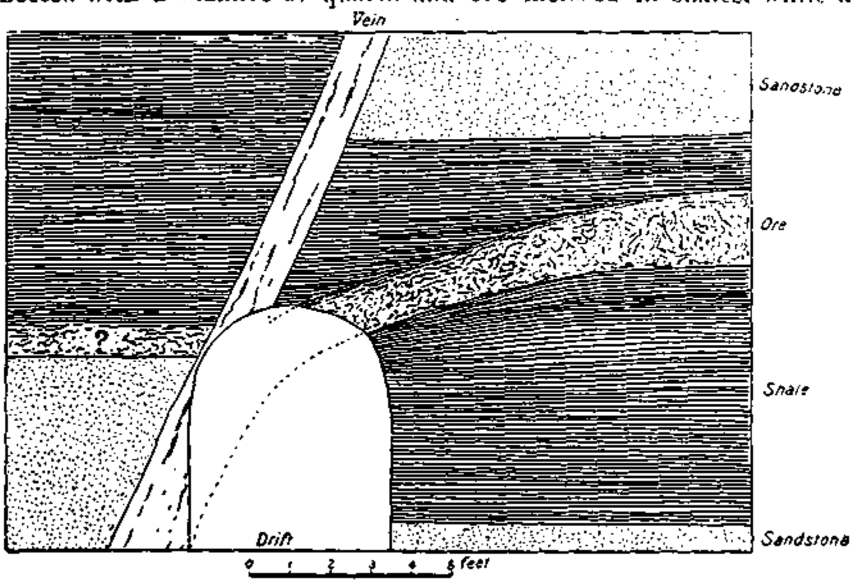


FIG. 64.—Cross section of the Sambo vein and blanket ore body, on the line A–A of fig. 63.

smaller portion of the vein continues upward across the beds (fig. 64).

The blanket deposit occupies a bedding fault between black shales below and gray calcareous shales above. The resulting shale breccia *is in places completely replaced by a mass of quartz and ore*, which extends to a distance of about 30 feet to the south of the drift. Beyond this the silicification dies out and the bedding fault is not mineralized. Owing to the inclusion of numerous shadowy fragments of silicified shale, the quartz has a decided mottled appearance.

The best ore consists of galena and tetrahedrite, but sphalerite is very abundant in some portions, together with pyrite and chalcopyrite. The stopes in the blanket indicate that considerable ore has been extracted, but the mine was idle at the time of visit.

The ore-bearing bedding fault has not been found on the north side of the vein, nor, apparently, has any search been made for it. The bedding fault is probably older than the vein, and was itself dislocated by the latter. It is very probable that the bodies of ore will some time be found on the north side of the fissure vein at a different level from those already extracted.

ZULU CHIEF MINE.

This is an abandoned prospect, situated near the head of Iron Draw, at an altitude of about 10,700 feet. It was opened through two tunnels, of which the lower is shown in plan in fig. 65. The workings are in shales, sandstones, and limestones of the Lower Hermosa formation, cut by at least one large dike of porphyry.

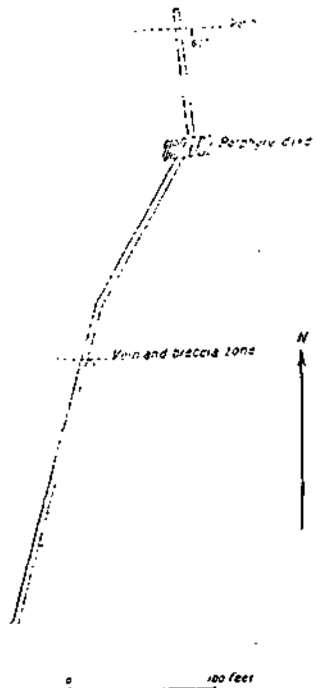


FIG. 65.—Sketch plan of lower tunnel of the Zulu Chief mine.

No ore was seen, and the chief interest in the mine is the occurrence of two strong fissures, cut by the tunnel, one of which probably corresponds to the Aztec lode fissure and the Nellie Bly fault. The first of these fractures is encountered about 200 feet from the mouth of the tunnel. It is a strong breccia zone about 10 feet wide, filled with fragments of shale and wet clay, with some quartz near the hanging wall. The dip of the fissure is southerly and its strike apparently nearly east and west, but neither could be accurately measured. The hanging wall shows shales and sandstones, while the very irregular footwall is limestone, which is shattered and irregularly veined with quartz for a distance of 50 feet from the fissure.

A second fissure, about 4 feet wide, was cut near the breast of the tunnel. The middle of the fissure is occupied by a vein of barren, banded quartz, 2 feet wide. This is separated from the hanging wall by 6 inches of gouge and broken shale, and from the foot wall by 18 inches of similar material with some soft oxide of manganese. This lode thus resembles, in general character, the Aztec. It strikes east and west and dips 60° to the south. The country rock near the breast of the tunnel consists of calcareous shales dipping N. 15° E. at 30°.

Besides the fissures described, several smaller ones, with general east and west trend, are intersected by the tunnel.

CALIFORNIA MINE.

This prospect lies near the head of Iron Draw, at an elevation of about 10,300 feet. There are two tunnels in limestones, sandstones, and calcareous shales, belonging probably to the middle division of the Hermosa formation. These are cut by dikes of monzonite-porphyry. The tunnels intersect several strong fissures, striking from N. 70° W. to S. 85° W. Most of these fissures contain gouge, with some quartz, and occasional bunches of galena ore, none of which have been rich enough to ship. In the upper tunnel are some blankets of pyrite, 6 to 8 inches thick, connected with one of the veins and replacing some disturbed beds of calcareous shale. A little native copper was noted in cracks in the sandstone in the lower tunnel. One or more of the fissures found in this prospect probably correspond to the Aztec lode.

MINES CONNECTED WITH THE BLACKHAWK FAULT.

BLACKHAWK MINE.

Situation.—The Blackhawk and Maggie mines, which have been worked in conjunction, lie on the northern side of the steep spur which separates Allyn Gulch from Silver Creek, in a shallow ravine marking the line of the great Blackhawk fault. This fault, as outlined by Cross and Spencer, can be traced from the saddle of Telescope Mountain, in which are the Uncle Ned and World's Fair mines, down to the Argentine shaft in Silver Creek, and thence up the Blackhawk ravine. Near the lowest level of the Blackhawk, at an elevation of about 9,800 feet, the fault fissure appears to split into two or more branches, and from here on, until it passes over the western shoulder of Blackhawk Peak, it is a zone of faulting rather than a single fracture. The Blackhawk mine lies on the northeastern edge of this fault zone.

History and development.—The mine has been worked through a series of tunnels ranging in altitude from 9,750 feet to about 10,600 feet. The highest opening is the Little Maggie shaft, an incline on the vein at 10,700 feet. As shown by the section (fig. 66), the vertical distances between these levels are not uniform.

The mine was first worked in 1879, and during the following years much high-grade oxidized silver ore was extracted from the Little Maggie vein, above the M level. From a varying distance above this level, up to the surface, the vein has been stoped out.

Below the M level the Little Maggie fissure, if it has been found, contains no workable ore. Large bodies of sulphide ore were discovered, however, on the northeast side of the vein. These are replacements in beds of limestone dipping away from the vein to the

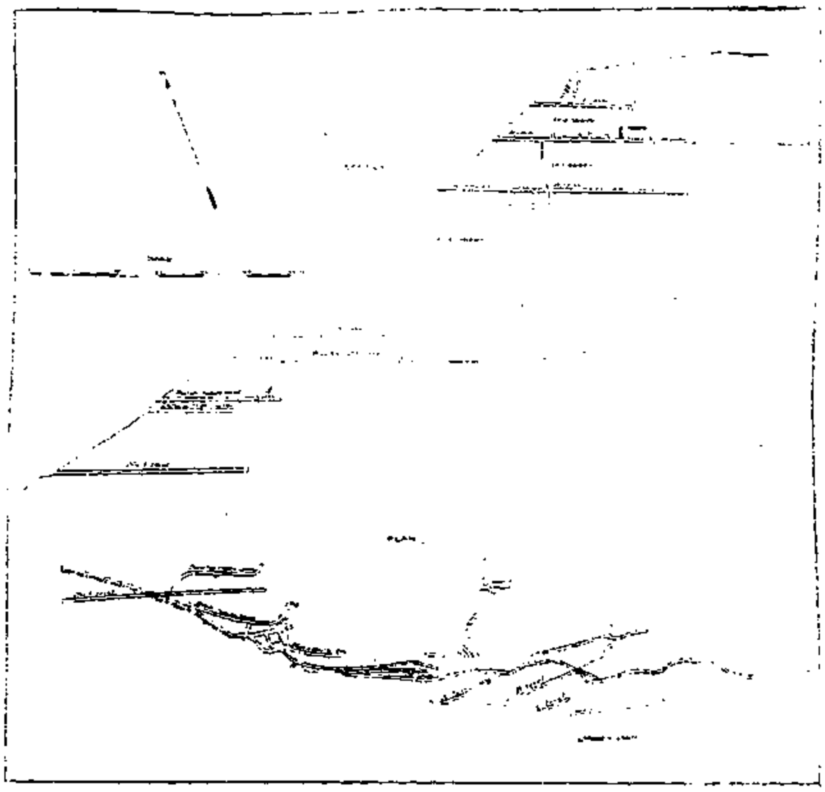


FIG. 66.—Plan and longitudinal section of the Blackhawk mine.

northeast, and were worked until about 1899, when the mine, for the time being, was abandoned.

Although most of the workings were accessible in 1900, yet the lack of clean exposures, and of some one at hand familiar with the mine, rendered the study of the ore bodies difficult and unsatisfactory.

Occurrence of the ore.—From the surface nearly down to the M level, a vertical distance of about 500 feet, the ore occurred in a simple fissure vein, striking about N. 70° W. and dipping northward at about 60°. This ore, which has all been stoped out, was a soft, black, earthy material, containing much oxide of manganese, largely derived from rhodochrosite. Toward the southeast, the ore body was limited by the contraction of the fissure to a small gouge seam. Toward the northwest the identity of the Little Maggie vein is lost at its junction with the Blackhawk fissure zone. The country rock consists of sandstones, shales, and thin limestones belonging to the upper division of the Hermosa, and dipping northeastward at about 30°. These beds are not perceptibly faulted by the Little Maggie fissure.

The relation of the Little Maggie vein to the Blackhawk fault is not perfectly clear. The general course of the latter is about N. 40° W., while the average course of the Little Maggie is N. 70° W. The Blackhawk fault is nearly vertical;[1] while the Little Maggie vein has a northeasterly dip of about 60°. As a consequence of these conditions and of relations of the fissures to the topography, the outcrop of the Little Maggie vein is practically parallel with the outcrop of the fault. About 150 feet southwest of the Little Maggie vein on the surface is a large solid vein of barren white quartz, in places fully 15 feet wide. The apparent strike of this vein is N. 40° W., corresponding to that of the Blackhawk fault, and it dips northeastward, seemingly at an angle of about 65°. Between this vein and the croppings of the Little Maggie is a much-disturbed and fissured strip of country rock traversed by many veins. This strip occupies the bottom of the little ravine which has been partly filled up by the dumps of the Blackhawk mine. The large southwestern vein has been only very superficially prospected, although it has apparently been cut in the Blacksmith level. It could not be determined whether it represents the main fissure of the Blackhawk fault, which is stated by Cross and Spencer to have a throw of from 600 to 800 feet in this vicinity, or whether this great dislocation has taken place along some fissure lying just southwest of the vein, and not prominently shown on the surface. The workings of the Blackhawk mine throw very little light upon the fault, inasmuch as they appear to lie entirely on its northeast side. Some years ago a tunnel 400 or 500 feet in length, known as the Wildcat, was run through Lower Hermosa beds in a direction N. 70° E., from the northeast side of Allyn Gulch, with the intention of crosscutting the country to the Little Maggie vein. The project, however, was abandoned, and the tunnel was not accessible in 1900. Had it been completed it must have crossed the Blackhawk fault. The lowest tunnel of the Blackhawk enters in monzonite-porphyry on the southwest side of the Blackhawk vein, with a course of S. 73° E. Its position and course indicate that it might afford much information in regard to the fault, but the presence of gas prevented its entry in 1900.

It seems probable that the Little Maggie vein joins or is cut off on the northwest by the more nearly northwest fissures of the Blackhawk fault zone, and that the principal veins drifted on in the M and

[1] Cross and Spencer, loc. cit., p. 117.

lower levels belong to this zone. Nevertheless, the Little Maggie should be cut somewhere in the northeasterly crosscuts on the M and Blacksmith levels. Several veins are intersected by these crosscuts, but none of them show the characteristics of the Little Maggie as known above the M level.

Below the M level the main Blackhawk vein has a course of about N. 65° W. and consists of barren quartz up to 5 feet in width. The hanging wall is usually regular and separated from the vein by a slight gouge. On the Blacksmith level, two parallel veins about 40 feet apart have been drifted upon, but apparently contained little or no ore, although bunches of pyrite are not uncommon.

Practically all the ore from the lower part of the mine was derived from large replacement bodies in a bed of massive limestone near the top of the middle division of the Hermosa. This bed, which is estimated to be nearly 30 feet in thickness, dips away from the vein to the northeast, at an angle of 25° or 30°. It outcrops just east of the Bunk-house level, exposing a large body of ore which has been extensively stoped. At this level the intersection of the ore body with the Blackhawk vein has been removed by erosion. The actual intersection of the ore-bearing limestone with the vein occurs just above the M level, where the Little Maggie oxidized ore stopped and the large bodies of sulphide replacement ore began.

These bodies of ore extend irregularly into the limestone to a maximum distance of 50 or 60 feet from the vein. They dip to the northeast, conforming to the dip of the limestone, and frequently attain a thickness of more than 15 feet. They are composed in great part of massive pyrite, of no present value, in which lie irregular bodies of workable ore. The best ore consists of fine-grained galena, chalcopyrite, sphalerite, and pyrite in a gangue of lilac and green fluorite. Such ore is often beautifully banded, the chalcopyrite and fluorite being disposed in thin concentric shells about centers irregularly grouped in the mass of ore as a whole. Ore of this character, being in large solid masses, with relatively little gangue, cleared about $10 per ton.

Such ore passes on its periphery into lower-grade ore, of which large quantities are still in the mine. This consists of massive, compact sphalerite and galena with a little chalcopyrite, and practically no gangue. It contains about 30 per cent of zinc, 20 per cent of lead, and up to 3 per cent of copper. This ore in turn sometimes grades into enormous masses of nearly pure pyrite, or is directly inclosed in limestone.

Near the Blackhawk vein the replacement ore bodies have a somewhat steeper dip and appear to turn up into the fissure. The ore, however, is not continuous with the material of the vein, the two being usually separated by a thin skin of gouge.

The upper portions of the large pyritic bodies are sometimes oxidized, and considerable cavities are formed by the solution and removal of the iron. Solution has also been active below the ore bodies, as shown in the M level, where the ore near the vein is underlain by a cavernous mass of rusty quartz, shown in Pl. XXVIII, *A*. This appears to have been formed by the removal of some soluble material, such as limestone or pyrite, from a network of quartz veinlets, and the subsequent deposition of fresh silica on the resulting skeleton.

As a rule there is no sharp wall between limestone and ore. The latter sometimes penetrates the white granular limestone in small irregular stringers and bunches, but more often the limestone next the ore is changed to jasperoid.

The limestone, and sometimes its included ore bodies, are cut by numerous fissures, some of which are small faults. In many cases these are mere gouge seams, obviously indicating movement since the ore was deposited. In other cases they contain quartz and pyrite, and were probably formed at substantially the same time as the main ore bodies. As a rule they have a general northwesterly course; but in the large stope east of the entrance to the Bunkhouse level a northeast fissure, carrying about three-quarters of an inch of banded quartz and ore, distinctly cuts the large ore body.

It is unavoidable that the foregoing description of the Blackhawk mine should leave many questions unanswered. The conditions are complex, and the opportunities for their investigation extremely limited. The existence of a great zone of faulting, from which several fissures, including the Little Maggie, branch off toward the southeast, has resulted in details of fissuring and fracturing which the present imperfectly mapped and unsystematic workings are wholly inadequate to unravel. But there is one clearly seen and important fact which vitally concerns the future of the mine. All the work on the replacement ore bodies has hitherto been confined to one bed of limestone at the top of the medial division of the Hermosa formation. But this entire division is composed chiefly of massive limestones aggregating several hundred feet in thickness. It is probable that the limestones below this upper bed, and extending down to Silver Creek on the northeast side of the Blackhawk fault, may also have been partly replaced by ore in the neighborhood of the fault zone. No effective prospecting has yet been done to determine whether ore bodies similar to those already mined may not exist in lower beds of limestone. Furthermore, the same limestones occur higher up Allyn Gulch and south of the Little Maggie shaft, on the southwest side of the Blackhawk fault. No attempt appears to have been made to determine whether these same Middle Hermosa limestones have been replaced by ore on this side of the Blackhawk fault zone.

ALLEGHANY MINE.

This lies northeast of the Blackhawk fault zone, and has been opened by two tunnels, the lower at 10,200 feet, and the upper at 10,300 feet in altitude. The vein strikes N. 70° W. and dips southwest at 72°. Like the Little Maggie vein it diverges to the southeast from the Blackhawk fault; but, unlike that vein, its southwesterly dip makes the divergence much more apparent on the surface. The workings are all in arkose sandstones and thin limestones of the Upper Hermosa, which the fissure does not appreciably fault.

In the upper tunnel the vein divides, one branch striking due southeast, a course which, if continued, must carry it into the Little Maggie vein.

The vein is filled with soft, oxidized silver ore up to 18 inches in width, which shows almost no quartz. It is said to have produced some argentiferous galena, but none was seen at the time of visit. It has been stoped between the two tunnels and above the southwest branch in the upper tunnel. The mine is at present idle and only partly accessible.

LEILA DAVIS MINE.

This lies immediately southeast of the Alleghany mine and on the easterly branch of the same vein. The main tunnel enters at an elevation of about 10,450 feet, while a second tunnel has been driven at 10,600 feet, and a third tunnel about 50 feet above the last. The vein strikes about N. 60° W. and dips southwest at 75°. The country rock is chiefly arkose sandstone in massive beds, part of which belong to the Upper Hermosa and part to the Rico formation, as mapped by Cross and Spencer. The vein filling is in all respects similar to that in the Alleghany ground, and has been stoped for a horizontal distance of about 300 feet and through a vertical distance of over 200 feet.

Owing to their opposing dips, the Alleghany-Leila Davis and Little Maggie veins may come together before reaching the ore-bearing limestone of the Middle Hermosa.

PRIVATEER MINE.

This is a prospect on the north side of Allyn Gulch, about 13,000 feet southeast of the Little Maggie shaft. It consists of a tunnel several hundred feet in length on a vein striking N. 70° W. and dipping northeast at 85°. This vein is in places 4 feet wide, but for most of the distance exposed is composed of crushed rock and gouge with but little quartz. The tunnel is partly in sandstone belonging to the Dolores and partly in an intrusive sheet of porphyry. The sandstones are not noticeably faulted by the fissure, although the abundant gouge shows that some movement has taken place along it. A little sphalerite and galena occur in the vein, but apparently no workable ore. The prospect is of interest on account of its proximity to the line of the Blackhawk fault, from which its vein appears to diverge in a manner similar to those of the Alleghany and Little Maggie mines.

ARGENTINE MINE.

This mine, situated in the bed of Silver Creek, on the line of the Blackhawk fault, was formerly worked through a shaft which is now abandoned and filled with water. There are also a few short tunnels on the south side of the creek, partly in a recent deposit of fragments of country rock from the hillside above, cemented by iron oxide.

The dump of the Argentine shaft shows limestone and sandstone as the prevailing country rocks. Coarsely crystalline pyrite is very abundant, and apparently occurred as a replacement mass in limestone, similar to that in the Blackhawk mine. It is reported by Gladford Smith, who last worked the mine, that the Blackhawk fissure runs through the shaft, but the ore occurs in another vein, trending northwest toward the Iron mine. This vein may coincide with the Last Chance fault, which is mapped by Cross and Spencer as passing near the Argentine shaft. The ore is said to have been about 3 feet wide and of low grade.

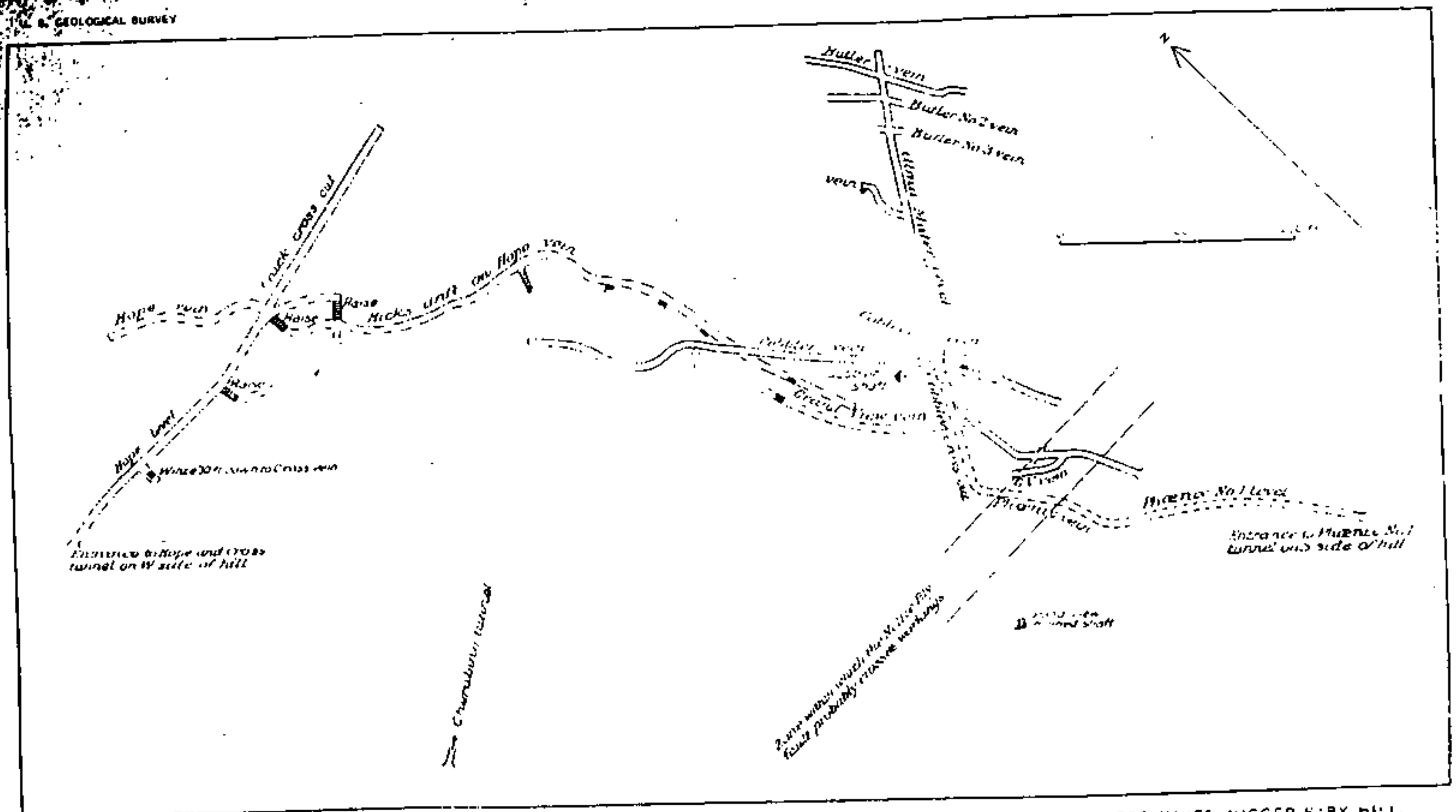
The country rock at the collar of the shaft belongs near the base of the Upper Hermosa; but the shaft undoubtedly penetrates the massive limestones of the medial division of the Hermosa formation.

UNCLE NED MINE.

This is situated in Uncle Ned draw, on the southwest spur of Telescope Mountain, in sandstones and shales of the Dolores formation. It is apparently on the Blackhawk fault fissure, but the workings are no longer accessible. The dumps show great quantities of quartz and pyrite, with a little sphalerite and galena.

WORLD'S FAIR MINE.

The workings of this mine lie just east of the Uncle Ned, on a vein striking N. 25° W., and thus diverging toward the north from the Blackhawk fault. The general dip is northwest at 75°. The vein, which has been opened by three tunnels, is oxidized and decomposed, and is accompanied by some gouge. It closely resembles the Little Maggie vein in general appearance, and has produced some silver-lead ore, but is now abandoned.



SKETCH PLAN OF A PORTION OF THE UNDERGROUND WORKINGS OF THE HOPE AND CROSS, PHŒNIX, AND ALMA MATER MINES, NIGGER BABY HILL.

MINES OF NIGGER BABY HILL.

GENERAL.

This hill was the scene of much of the early mining activity of the district. The ground is covered with claims which have been repeatedly abandoned and relocated, causing much confusion of names, and the hill is honeycombed with disused workings. Only a few of the more important of the latter will be described in the following pages, and no attempt will be made to adhere closely to the artificial divisions arising from individual ownership of various portions of this complex network.

GRAND VIEW GROUP.

This comprises the Grand View, Phœnix, Yellow Jacket, Major, and Pelican claims, covering some of the earliest locations in the district. These claims lie on the main spur and south slope of Nigger Baby Hill, ranging in altitude from about 10,050 feet at the old Cobbler shaft, on the nose of the hill, down to about 9,600 feet at the fourth level of the Phœnix workings, on the slope north of Silver Creek. They lie largely within the block of Middle and Lower Hermosa beds, which is bounded by the Nellie Bly fault on the north and the Last Chance fault on the south. Within this area the extensive workings have revealed numerous veins having general courses varying from N. 25° to N. 60° W. and dipping northeast at angles of 15° or 20° to vertical. The great number of these veins, the thorough oxidation and decomposition of their upper portions, the unsatisfactory outcrops, and the numerous faults which Cross and Spencer have shown to traverse the hill, render the study of these ore deposits exceedingly difficult. The former workings, moreover, were very poorly mapped and are now abandoned. Some of them are entirely inaccessible.

In 1900 the only way of examining the upper portions of the workings, including the old stopes, was by passing through the abandoned and caving drifts and inclines which connect the Phœnix No. 1 and Hope and Cross tunnels (Pl. XXXIX). The condition of these old workings was such that it was deemed prudent to confine their study to a single trip through them.

If accurate maps of all the Nigger Baby Hill workings were available and could be plotted on one sheet to the same scale, much light would undoubtedly be thrown on the perplexing problems presented by these veins; but the data for such a procedure are unfortunately not obtainable.

Three important veins have been worked in the Grand View mines. These are the Phœnix, Grand View, and Cobbler veins. They have a common strike of about N. 30° W. and on the Phœnix No. 1 level, where all three veins are exposed, something over 200 feet below the surface, they are about 50 feet apart. The Cobbler vein was originally worked from a shaft sunk on the summit of Nigger Baby Hill at an elevation of 10,060 feet. Near the surface the vein dipped northeasterly, but at the Phenix No. 1 level it is vertical. This vein is small, but produced some excellent oxidized ore, and was continuously stoped from the surface down to the Phenix No. 1 level (see fig. 67). At this depth the vein has a northeasterly dip of 80°, but is less steep in the Alma Mater level above, especially when followed northward. On the Phenix No. 1 (Grand View No. 4) level the vein shows a width of about 8 inches in massive sandstones and a little shale. The vein is composed of an impure calcite associated with an abundance of the oxides of manganese and iron, and containing little vugs and druses of

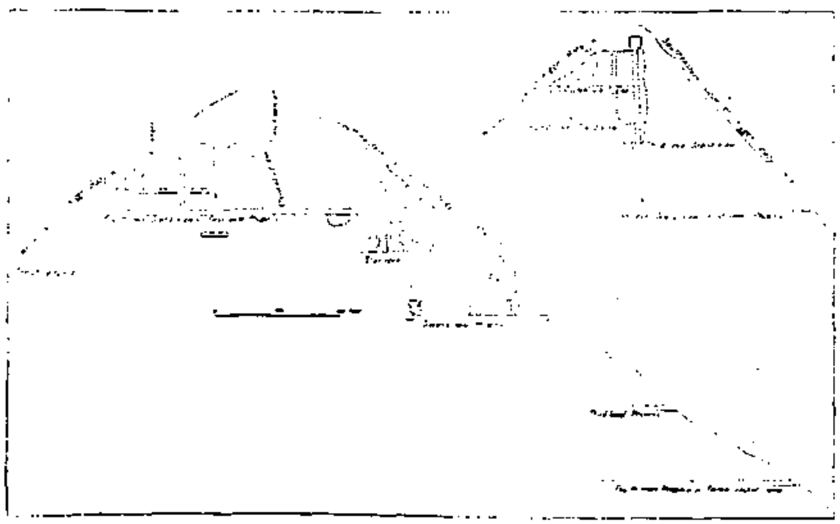


FIG. 67.—Longitudinal sections through the Grand View and Phenix veins.

white calcite. It contains practically no workable ore at this level, and presents a condition intermediate between the thoroughly oxidized ore above and an unoxidized vein filling composed of low-grade sulphide ore in a calcite gangue.

At the southeastern end of the drift on the Cobbler vein are two cross fissures, striking N. 60° E. and dipping northwest at from 40° to 65°. These fissures are filled with soft gouge and are younger than the Cobbler vein; but they do not appear to fault it. In this end of the drift are massive limestones, presumably belonging to the Middle Hermosa, and some intrusive masses of porphyry. The presence of the limestone suggests that the Nellie Bly fault may cross this drift, but the exact location of the fissure could not be discovered.

The Grand View vein, on this level, lies 50 or 60 feet southwest of the Cobbler. It was formerly worked through the Grand View inclined shaft, which entered the hill at an elevation of about 10,000 feet in massive limestones, belonging to the middle division of the Hermosa formation, and followed down the dip of the vein. Somewhere in its course it is supposed to have passed through the Nellie Bly fault,[1] but as the shaft is timbered up, the rocks which it penetrates are not exposed on the Phœnix and Hicks levels (Pl. XXXIX), and in the stopes between them the Grand View vein (known as the Hope vein in the Hope and Cross workings) shows a variable dip up to 60°. When the dip is steep, the vein is small and cuts across the beds of shale and sandstone belonging probably to the Upper Hermosa. But where the dip flattens, as it does some distance above this level, and above the Hicks drift to the northwest, the vein is larger, and often follows the bedding planes for some distance. In such cases it may be 18 inches wide. It is composed of soft, oxidized material containing much oxide of manganese. Above the Phœnix No. 1 level this material was usually rich in silver.

The Phœnix vein lies about 50 feet southwest of the Grand View and is parallel to the latter in strike. At the Cobbler crosscut, the Phœnix vein dips northeast at only 15° or 20° and follows a bed of decomposed shale, about a foot thick, lying between relatively massive beds of sandstone. The vein, steepening its dip in places, carried soft oxidized ore from the Phœnix No. 1 level out to the surface, and has been extensively stoped.

South of the Cobbler crosscut the Phœnix No. 1 level follows a nearly vertical vein carrying partly oxidized galena in a decomposed gangue of impure calcite. This vein has the same strike as the flatly dipping Phœnix vein, and does not appear to fault the latter. It is probably merely a branch of the Phœnix fissure.

About 100 (?) feet south of the Cobbler crosscut the hanging wall of the Phœnix vein changes to massive limestone. The vertical fissure apparently turns abruptly to the west at this point, but the Phœnix vein, dipping 25° or 30° to the northeast, continues toward the mouth of the tunnel. Much good ore was stoped beneath the limestone in this part of the vein.

The Grand View vein has apparently not been worked below the Phœnix No. 1 level, but the Phœnix vein has been extensively stoped for an additional depth of over 150 feet down to the Phœnix No. 2 level. Between the Phœnix No. 1 and Star levels (see fig. 67) the general dip of the vein is 30°. The ore removed was soft, oxidized material, and appears to have frequently had a width of 4 or 5 feet. It lay between walls of fine-grained, massive sandstone.

A crosscut toward the southwest, and therefore into the foot wall, shows numerous veins of steeper dip than the Phœnix, which probably run into the latter above. These vary in strike from N. 45° W.

[1] Cross and Spencer, loc. cit., p. 118.

to N. 80° W., and in dip from 50° to 85° to the northeast. These veins are composed of the soft, black, manganiferous material so common as a vein filling in the upper portion of Nigger Baby Hill. They traverse massive limestones and sandstones probably belonging to the Hermosa formation.

Below the Star level the Phœnix vein is less thoroughly oxidized. The old stopes show that the vein frequently pinched to a width of only 2 or 3 inches. In these narrow portions the ore consists of galena, partly changed to cerussite, with some sphalerite and pyrite, but practically no gangue. This ore lies between a hanging wall of sandy shale and a foot wall of fine-grained sandstone, and follows the bedding for some distance. Judging from the character of the stopes, the value of the ore was to some extent proportional to the degree of its oxidation.

On the Phœnix No. 2 level the country rock, consisting chiefly of massive sandstones of the Hermosa formation, is traversed by three steeply dipping veins. One strikes N. 70° W. and has a variable but generally vertical dip. It is very irregular, containing a little pyrite and oxidized material, but no ore. A second vein strikes N. 60° W. and dips northeast at about 70°. This carries pyrite, sphalerite, and chalcopyrite, and is in places 2 feet wide; but the ore is apparently of too low grade to extract. From the southwest side of this vein a flatter vein, dipping 40° to the northeast, branches just above the level. This vein carries a little galena ore and has been stoped. It is possibly the Phœnix vein, but the old stopes, in which alone the identity could be established, were not accessible at the time of visit.

The third nearly vertical vein is cut near the mouth of the level. It strikes N. 80° W. and dips southwest at 60°. Its filling is barren quartz about 6 inches wide. The dip and filling of this vein are different from those usually observed on Nigger Baby Hill. It is poorly exposed, and its relation to the other veins on the level is not apparent.

On the third level of the Phœnix the main drift follows a small, solid, unoxidized vein containing much sphalerite in a calcite gangue. This vein strikes N. 55° W. and dips northeast at 60°. An incline that was run up on the fissure for about 40 feet shows that this vein, which is beautifully banded, diminishes in width, lessens its dip to 35°, and finally breaks up into a network of small stringers in fine-grained Hermosa sandstone. From the top of this incline an inclined crosscut was run into the hanging wall for about 20 feet. This opened up a second generally parallel vein striking N. 60° W. and dipping northeast at 45°. This is a solid vein, containing abundant low-grade sphaleritic silver-lead ore in a calcite gangue. It has been stoped to some extent, and the workings extend up to the Phœnix No. 2 level, showing that it is probably the Phœnix vein. On the main No. 3

level this vein has decreased in width. It probably dies out, as the overlapping vein a few feet southwest of it grows larger. A winze on the latter vein shows that it, and not the original Phenix, is the vein followed in the Phenix No. 4 level.

The No. 3 level ends in a crosscut running N. 30° E. The breast of this crosscut is in massive crinoidal limestone of the Middle Hermosa, resting upon sandstone. The dip of the beds is 35° to the northeast. The veins on this level appear to follow the bedding planes in the main.

The fourth and lower level of the Phenix mine is caved and inaccessible. Apparently several veins similar to those just described were prospected, but the ore was too poor to pay for working.

ALMA MATER MINE.

The principal level of this mine is shown in Pl. XXXIX. Lying about 50 feet above the Phenix No. 4 level, it connects with the Grand View workings through the Cobbler vein, and on the east with the Butler mine. Probably nowhere at present accessible in Nigger Baby Hill can a better idea be obtained of the number of northwesterly veins which traverse the hill than in the Alma Mater level. It is essentially a northeasterly crosscut, connecting with drifts on at least six veins. The Nellie Bly fault is supposed to cross the tunnel about 75 feet from its mouth,[1] but the ground in this vicinity does not permit the certain identification of the fault fissure. There is much oxidation and decomposition and several irregular seams of gouge at this point, apparently connected with the Grand View vein. Beyond the Grand View vein the rocks are chiefly sandstones, frequently somewhat shaly, belonging probably to the Upper Hermosa beds.

The Cobbler vein, as seen on this level, is a nearly vertical sheeted zone in sandstone, containing streaks of oxidized ore up to 1 foot wide. It has been extensively stoped.

Between the Cobbler vein and the Butler group of veins, at least four veins, ranging in strike from N. 25° W. to N. 45° W., and dipping northeast, are cut by the crosscut. Upon one only has any work been done. The filling of these veins is rather fine-granular impure calcite, containing minute specks of sulphide ore, and more or less thoroughly decomposed to the soft, black manganiferous material already described. In hand specimens the undecomposed vein filling shows slight banding parallel to the fissure walls, but in thin section, under the microscope, can not be distinguished from an ordinary limestone slightly mineralized. The microscope shows that the alteration extends irregularly into the calcite as minute dark specks and dendritic patches, which become more closely aggregated as the change proceeds, until

[1] Cross and Spencer, loc. cit., p. 118.

the calcite is all removed and a pulverulent black mass, largely oxide of manganese, remains.

The Butler group consists of three parallel veins about 25 feet apart. The one nearest the mouth of the tunnel is known as the Butler No. 3, or Little Butler vein. It has been stoped, and is said to connect with the workings of the Butler mine, to the southeast. But practically nothing of the vein could be seen at the time of visit.

Northeast of the Butler No. 3 lies the Butler No. 2 vein, striking N. 25° W. and dipping northeast at 65°. This is a solid "spar" vein, 8 inches wide, showing almost no oxidation, and containing abundant sphalerite and a little pyrite and galena in a gangue of calcite. Much of the calcite is slightly pink, and probably contains manganese carbonate.

Northeast of the Butler No. 2 is the Butler vein, striking N. 30° W. and dipping northeast at 70°. This is similar to the preceding, but more oxidized. Considerable work has been done on this vein and some ore was extracted.

HOPE AND CROSS MINE.

This mine was probably the first on Nigger Baby Hill to produce ore in commercial quantities. It was originally worked in 1882 and 1883 by inclined shafts. It is now opened by a tunnel, situated on the western slope of the hill at an altitude of about 9,850 feet. The workings from this tunnel are continuous with those of the Grand View group (see Pl. XXXIX). Two nearly parallel veins are recognized, striking about N. 30° W. and dipping at low angles into the hill to the northeast. The upper and more easterly of these veins is the Hope, which is the same as the Grand View vein, as shown by continuous drifting. The dip of this vein is very variable. It frequently follows the bedding of the shaly sandstones for some distance, with a dip of about 20°, and then turns up across the beds with dips as high as 45°. It is filled with soft, decomposed material, much of which, being rich in silver, has been stoped out.

The Cross vein lies southwest of and below the Hope, the distance between them being about 45 feet. This vein is below the tunnel level, and is cut at the bottom of the winze shown in Pl. XXXIX. It shows much disturbance at this point, and consists of a streak of decomposed rock, clay, and black oxide of manganese, underlain by decomposed sandstone, which is shattered to a distance of 2 or 3 feet from the vein. The hanging wall is a micaceous sandy shale, also much disturbed. The best and most abundant ore is found in the flatter portions of the vein. It is distinguished from the worthless oxidized material by the presence of specks of copper carbonate. The maximum thickness of the ore is 3 feet, but the usual thickness is from 4 to 8 inches. It contains on an average from 150 to 300 ounces of silver per ton, although some ore running as high as 1,500 ounces per ton has been shipped.

In its position with reference to the Hope or Grand View vein, the Cross vein corresponds to the Phœnix. It would be unsafe, however, to assume their identity in a locality where fissures of like trend are so numerous, and where there has evidently been so much disturbance.

A little north of the Hope and Cross tunnel, and 96 feet vertically below it, a tunnel has been run to cut the Cross vein at a more convenient point for working it. About 250 feet from its mouth it cuts a strong fissure striking N. 40° W. and dipping at 45° or 50° to the northeast. It is from a foot to 18 inches wide and very regular. It contains some crushed quartz, clay, oxide of manganese, and gouge next the walls. But although much drifting has been done along this fissure, upon the supposition of its being the Cross vein, only traces of ore have been found. It seems probable that the foregoing supposition (now abandoned by the prospectors) is correct, in spite of the lack of ore, and that this fissure is continuous with that known as the Cross vein in the upper workings. But, as is often the case in prospecting, a little accurate surveying is the last resort, rather than the first preparation.

Scattered thickly over the hillside between the Hope and Cross and Grand View adits are a number of little tunnels, from some of which rich ore was being shipped in 1900. They lie to the north of Nellie Bly fault, in sandstones and shales of the Upper Hermosa, which, at the fault, are brought into juxtaposition on the south with massive limestones of the Middle Hermosa.

With the exception of a small stringer of galena, all the ore is of the usual oxidized character and comes from the superficial portions of the Cobbler, Grand View, or Hope, Cross, and other veins. One lot of about 20 tons, shipped in 1900, was valued at about $2.50 per ton. Most of these workings are too shallow and irregular to merit special description.

NELLIE BLY MINE.

The chief interest of this little mine is in connection with the great fault to which it has given its name. The workings consist of two tunnels on the south slope of the hill—one at an elevation of about 9,900 feet, and the other approximately 50 feet below it. The two are connected by a winze. The lower tunnel, shown in fig. 68, is a crosscut through shales, sandstones, and intrusive porphyry, and in 1900 was being extended with the object of tapping the Butler veins. About 125 feet from its mouth the tunnel cuts an east-west fissure, dipping north at 85°. This fissure is only 3 or 4 inches wide, and is filled with tightly squeezed crushed rock. It is probably the Nellie

Bly fault, although the shales on each side of the fissure at this point are apparently identical. A vertical upraise on this fissure finally opened up the Nellie Bly vein, presumably at the intersection of the latter with the fault plane.

The work of the Nellie Bly vein is all on the level of the upper tunnel. This enters in massive gray limestone belonging to the medial division of the Hermosa formation. But about 6 feet from the mouth the limestone is cut off by a fault and the tunnel passes into fine-grained shaly sandstones belonging to the upper division of the Hermosa. The fault strikes north 75° east, and dips north at 80°. The fissure is clean cut, about 4 inches wide, and filled with firmly squeezed

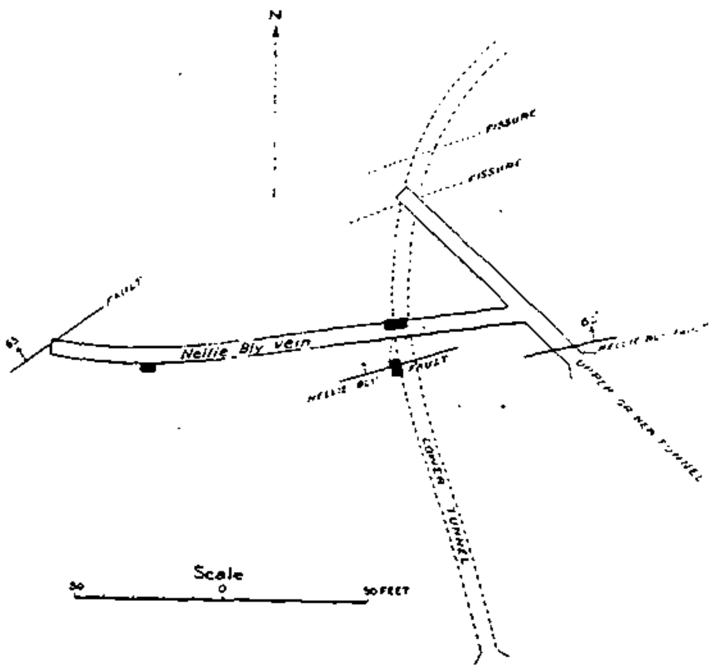


FIG. 68.—Sketch plan of the Nellie Bly mine.

crushed rock. The only trace of mineralization consists of slight staining by oxide of iron. There can not be much reasonable doubt but that this fissure is identical with that noted in the lower tunnel, and is the Nellie Bly fault as supposed by Cross and Spencer. The throw as observed at the Nellie Bly is certainly over 6 feet, and is probably many times this amount. These writers, however, sometimes speak of the fault as if it were synonymous with the Nellie Bly vein. This is a misapprehension.

The Nellie Bly vein, which closely resembles the Grand View vein, and may possibly be identical with it, has a strike generally parallel to that of the fault fissure, and, on the level of the tunnel, is separated from the latter by about 20 feet (fig. 68). The Nellie Bly vein dips north at from 40° to 55°. The Nellie Bly fault is nearly vertical. The two probably intersect in the stopes above the level, and this led to the discovery of the vein through a raise started originally on the fault from below. The footwall of the Nellie Bly vein is porphyry, the hanging wall, sandstones, and shales dipping north at 20° or 25°. The vein and its porphyry footwall, having a steeper dip, cut these beds at a small angle, although thin seams of vein matter often extend out in the planes of bedding toward the north.

The vein matter of the Nellie Bly is composed chiefly of the sooty alteration product common in the veins of Nigger Baby Hill, with sometimes a little white "sugar" quartz and irregular masses of fine-grained yellowish calcite. A chemical analysis of some of this vein-filling is given on page 267. The particular sample analyzed came from a portion of the vein not regarded as ore, but it illustrates well the general nature of the material so characteristic of the upper portions of the Nigger Baby Hill veins. In some of the stopes above the level the vein has a width of 2 to 3 feet, consisting of the above material traversed by broken stringers of quartz and containing residual nodules of impure calcite. In some places, where alteration has been complete, the calcite or "spar" is 5 feet in width.

The Nellie Bly vein was drifted on and stoped for a distance of about 160 feet from the tunnel to a point where it is cut off on the west by a fault striking N. 55° E. and dipping northwest at 65°. The fault fissure contains soft, yellow clay gouge between broken and slickensided walls. The Nellie Bly vein is sharply deflected or dragged to the south at the intersection with the fault.

The product of the Nellie Bly vein is reported to have amounted to about $8,000. The main tunnel on this level follows a small partly oxidized "spar" vein, dipping southwest at 85°. The country rock shown is sandstone, apparently dipping north at 25°. A little ore was taken from this vein in a raise near the breast.

IRON MINE.

This mine, located in 1882, lies on the southeastern slope of Nigger Baby Hill, the main adit being a tunnel at a little over 9,300 feet in altitude. This tunnel is between 800 and 900 feet in length, and with the exception of a crosscut of about 75 feet near its mouth, follows a vein striking N. 16° W. and dipping easterly at from 60° to 85°. This vein can be traced on the surface, up the ravine above the mine, to the saddle behind Nigger Baby Hill in which is the Bourbon prospect on the same fissure.

The country rock exposed in the main tunnel consists of sandstones, limestones, and shales. For a little over half its length the tunnel is in beds belonging to the middle division of the Hermosa formation, including several strata of limestone. But for a distance about 400 feet outward from the breast, sandstones and firm shales are the only rocks met with. These probably belong to the upper division of the Hermosa. This change from one set of beds to another is probably due to the Nellie Bly fault, which, as mapped by Cross and Spencer on the surface, must pass through the tunnel. Careful search for this fault, underground, failed to satisfactorily demonstrate its presence. But it is believed that the accompanying partly diagrammatic section (fig. 69) represents the most reasonable interpretation of the observed facts.

About 450 feet from the mouth, the tunnel passes through a bed of

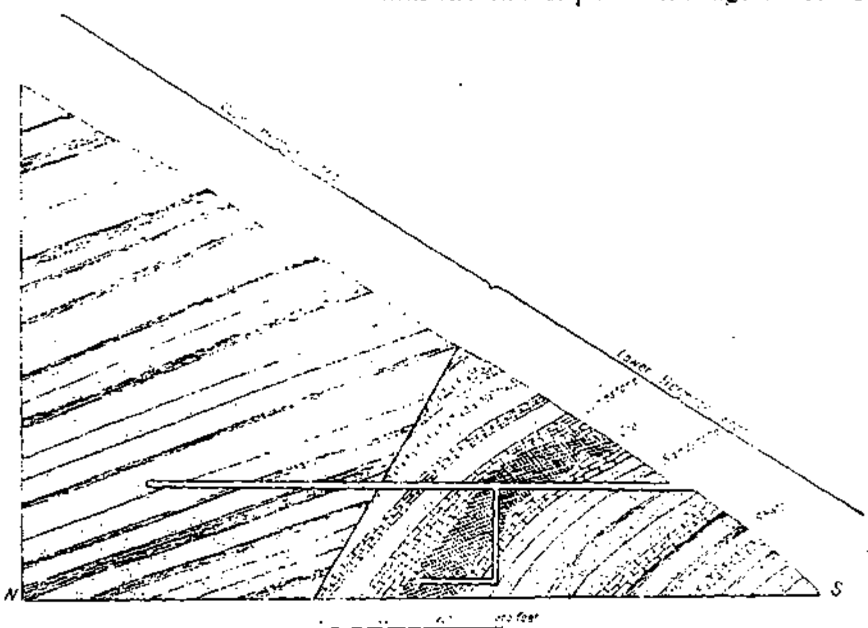


FIG. 69.—Diagrammatic longitudinal section through the Iron mine.

limestone containing crinoid stems and evidently belonging to the lower division of the Hermosa. This bed and the sandstones underlying it dip north at about 50°, flattening somewhat above the tunnel. The limestone is succeeded on the north by sandstones and shales of much lower dip—only 20°. Between the limestone and the bed of sandstone just north of it is a vein of crushed banded quartz about 4 inches wide, which probably fills the Nellie Bly fault fissure. Owing, however, to the similarity in dip between the fault and limestone at this point, and the fact that the limestone is overlain by sandstone similar to that brought into juxtaposition with it by the fault, it is impossible, in so limited an exposure, to be certain that the vein really traverses the beds, instead of lying between them.

The Iron vein is not appreciably dislocated by the fault. Near the mouth of the tunnel, in sandstone, the vein is over 5 feet wide and consists of two portions. Next to the hanging wall is a fairly solid mass of banded quartz from 4 to 10 inches wide. The rest of the vein consists of disturbed quartz and country rock. Beyond the fault the vein is usually smaller. Calcite is a common gangue mineral throughout and at the breast is particularly abundant. It contains much sphalerite and some pyrite, and has a faint pinkish tint, suggesting the presence of a little manganese. It resembles the material found in the Butler No. 2 vein on the Alma Mater level (p. 380). With the exception of a pocket of tetrahedrite ore, found about 40 feet above the tunnel and 360 feet from the breast, the Iron vein proper contains practically no ore where shales or sandstones form the country rock. But where the fissure traverses the limestone beds of the Middle Hermosa formation these are replaced by ore to a width of from 6 to 12 feet. The main ore body is over 100 feet in length and occurs in the largest bed of limestone cut in the tunnel (see fig. 69). This ore was stoped upward, on the dip of the bed, to the surface. It was followed down by a vertical winze 150 feet deep, which, owing to the northward dip of the limestone, ran through the bottom of the ore. The latter was recovered by drifting north from the bottom of the winze. Ore was also found extending into the limestone for some distance from the vein, following fissures which dip about 40° to the southwest and come to the main vein from the northeast. The ore is usually massive, consisting chiefly of pyrite and chalcopyrite, in a calcite and quartz gangue. A little galena is sometimes present. The material stoped contained from 40 to 70 ounces of silver per ton, 2 or 3 per cent of copper, and 30 per cent of iron.

Owing partly to the fact that the main ore body can no longer be cheaply worked from the tunnel level the mine is now idle. The winze was filled with water at the time of visit, so that nothing could be seen of the ore body below the tunnel level. It probably follows the bed of limestone down to a considerable depth, until perhaps ultimately cut off by the Nellie Bly fault.

LAST CHANCE MINE.

This is a prospect situated on the trail, about 800 feet southwest of the Iron mine. It consists of a tunnel about 200 feet long on a fissure having an average course of N. 80° W. and nearly vertical. This fissure contains a strong but variable vein composed of quartz, pyrite, and a little chalcopyrite. It differs from the other lodes of Nigger Baby Hill, but its chief interest is connected with the statement of Cross and Spencer,[1] that it corresponds to the Last Chance fault, which brings up Algonkian quartzite on the south against monzonite-porphyry

[1] Loc. cit., p. 119.

on the north. The actual fault may be parallel with the vein, and is certainly very close to it. But the walls of the vein fissure are both porphyry, much altered and impregnated with pyrite. It is probable that the porphyry on the south wall is a thin skin only, separating the vein from the actual fault plane.

MINES OF C. H. C. HILL.

GENERAL.

That portion of the western slope of Telescope Mountain known as C. H. C. Hill is practically coextensive with the large landslide mass which covers the slope from an altitude of about 11,750 feet on the east down to the Dolores River on the west, crowding the latter stream over against the base of Sandstone Mountain.[1] Like its neighbor, Nigger Baby Hill, C. H. C. Hill is penetrated by a labyrinth of workings, many of them extensive and most of them abandoned and inaccessible. The more important mines are owned and worked in groups, as follows:

Group.	Claim.
Wellington group	Wellington.
	Zona K.
	C. S. and H. H.
	Maid of Australia.
	Lottie.
Logan group	General Logan.
	General Sheridan.
	General Howard.
	General Sherman.
	Little Casper.
	Goliath.
C. H. C. group	C. H. C.
	Athlena.
	Limestone.
	Princeton.

The Crebec mine, closely connected with the Princeton, and the Pigeon mine, on the northwest portion of the hill, have also been important. The following descriptions will adhere to this grouping only so far as is convenient in a region of such irregular and interlacing workings. No good maps exist for any of the mines.

At the present time work is restricted to prospecting in the Wellington and Logan groups, the extraction of a little ore, by leasers,

[1] See Cross and Spencer, op. cit., pp. 136-141, for fuller account of this landslide area.

from the Princeton mine, and some development on various less important properties. It is exceedingly doubtful whether any of the ore taken from the C. H. C. hill has come from rock in place.

WELLINGTON GROUP.

The ore in this group occurs in a so-called "contact," or blanket zone. This was originally worked through the Wellington shaft, now abandoned. The main adit at present is the Mountain Spring tunnel, situated almost directly opposite the mouth of Horse Gulch, at an elevation of about 9,500 feet. This tunnel extends for 940 feet in a direction N. 75° E. For 210 feet it passes through loose surface detritus, and then enters sandstones and shales, generally badly shattered and disturbed. Where the bedding of these rocks is not obliterated they may be seen dipping at variable low angles to the southwest. But more often the beds are reduced to a chaotic jumble of large fragments, separated by clayey material. Two dikes of white quartzose porphyry and a few small stringers of quartz are intersected by the tunnel. These are all broken and displaced. Much of the sandstone in the tunnel is bleached nearly white by removal of the iron originally present in its constituents.

An upraise of 85 feet from the breast of the tunnel gives access to the Zona K. level, which is run beneath the main "contact" and connects with the Sheridan and Logan workings, and formerly connected with the Princeton and C. H. C. mines. The rocks exposed on this level are fine-grained, nearly white, noncalcareous sandstones and compact limestones. These are much fissured and faulted, but somewhat less disturbed than the rocks in the Mountain Spring tunnel. Little regularity can be recognized in these fissures. They are small irregular fractures, containing soft clay gouge, but no quartz. The general dip of the beds is from 10° to 30°, in a direction a little east of south.

Above the level, resting sometimes on a fine-grained, nearly white, micaceous sandstone and sometimes on limestone, is the "contact," composed chiefly of loosely cohering limonite and yellow clay up to 5 feet in thickness. It dips generally to the southwest, but is rolling and uneven, as well as variable in thickness. It is overlain by sandstone.

In the northeastern part of the workings the "contact" has risen, so that it lies just above the Sheridan level (really in ground belonging to the Logan group), which is 80 feet above the Zona K. level. It is here evidently a plane of faulting, being filled with fragments of sandstone, yellow and gray clay, and limonite. It is also traversed by seams of very tenacious soft gouge. This brecciated material passes with no sharp division into the overlying fractured sandstone, called by the miners "porphyry," or the "mineral roof." The thickness of the blanket zone ("contact") varies in this portion of the workings from 1 to 5 feet. The ore, when present, usually occurs the lower portion in the form of argentiferous oxide and carbonate of lead. None, however, was seen at the time of visit.

At the northeast breast of the main Sheridan level the blanket zone lies 25 feet above the drift. It turns upward near this point, toward the southeast, following a very smooth but undulating slip plane. The general strike of this plane is northeast and southwest. The average dip is about 45° to the northwest. The blanket zone, where it follows this fissure, lies between two seams of clay gouge, and contains a little partly oxidized galena ore.

At a vertical distance of 25 feet above the Sheridan level lies a portion of the Logan level. This formerly connected with the Logan tunnel and shaft, but is now reached through the Wellington workings. It lies just north of the latter.

Portions of this level are run in the main "contact," here about 100 feet higher than where first described, above the Mountain Spring tunnel. This difference is partly due to a general southerly dip, but is said by those who worked in the old stopes, now caved in, to be in part due to successive step faults of small individual throw. Large bodies of pyrite occur in the "contact" on the Logan level, and it is without doubt from the oxidation of similar bodies that there has resulted the crumbling limonite so abundant in other portions of the "contact."

A crosscut to the northeast, near the old Logan shaft, cuts through 15 feet of loose crumbling pyrite into what is known as "the big fissure." This is an enormous lode of crushed quartz and pyrite, which will be more fully noticed in the newer Logan workings and in the Pigeon mine.

Owing to the lack of surface exposures and the great disturbance of the entire hill, it is difficult to determine the exact horizon of the sandstones, shales, and limestones met with in the Wellington mine. The difficulty is increased by the very prevalent bleaching and alteration of the sandstones, so that they resemble no beds found elsewhere in the region. It is believed, however, that they belong to the upper division of the Hermosa.

PRINCETON MINE

These workings lie about 700 feet south of the Mountain Spring tunnel, and were formerly connected underground with those of the Wellington group. The Princeton ore occurred in a blanket, said to be continuous with that of the Wellington group. It was worked through an adit tunnel which enters the hill at an elevation of about 9,600 feet, and runs N. 61° E. for about 400 feet.

None of the old Princeton workings are now accessible. The landslide in which they lie is still creeping slowly down the slope, so that

DRIFT IN THE PR[illegible] MINE [illegible]

[illegible]

timbers originally set in an upright position are soon thrown out of plumb. The effect of this movement is speedily blocking abandoned drifts, is shown in Pl. XL, from a photograph taken by G. W. Tower, in 1898, near the end of the main tunnel. It illustrates well the difficulties attending the study of abandoned workings in the Rico region. This tunnel, and a long irregular drift to the Crebee shaft in the southeast corner of the mine, has since been reopened by leasers who, in 1900, were taking out a little ore containing 40 to 60 ounces of silver and considerable lead from the Crebee ground.

This ore occurs in a blanket said to be continuous with that formerly worked in the Princeton. Near the Crebee shaft the blanket, or "contact" as it is called, is about 50 feet from the tunnel level, but comes down to the latter near its mouth. The dip, while generally southwest, is very variable and the mass is minutely faulted by numerous small fractures. The blanket rests on hard, fine-grained shattered sandstone without any very sharp line of separation between the two. The sandstone is buff in color and noncalcareous. The quartz grains are held together by an abundant ocherous cement of uncertain character and probably of secondary origin. The blanket is overlain by gray shales, often much shattered.

The material composing the blanket varies from place to place. It sometimes consists of a cellular or loosely cohering mass of limonite 4 feet in thickness, containing fragments of sandstone and limestone. These are evidently in part residual masses; the limestone especially being surrounded by soft shells of decomposition or alteration. In other portions of the workings the lower one, to 3 feet of the blanket, consists of yellow, clayey material, near the top of which is a streak of a few inches of soft, ocherous ore containing a considerable amount of silver. Above this there is usually about 8 inches of soft, gray banded ore, commonly referred to as "carbonate ore." This, however, is a misnomer, as it contains no appreciable quantity of carbonates. It is in considerable part impure, pulverulent lead sulphate. Some of the bands are composed of a snowy-white substance, locally called "talc," which crumbles between the fingers to a fine harsh powder. A rough chemical examination of this material by Dr. Hillebrand shows it to contain about 83 per cent of silica, over 5 per cent of water, and about 9 per cent of lead sulphate. Under the microscope the powder is apparently amorphous. The silica is probably in the opaline form. In composition and physical properties it closely resembles tripolite or infusorial earth. But it shows no trace of organic structure, and is undoubtedly a product of chemical alteration connected with ore deposition.

Large lenticular bodies of iron pyrite occur at several horizons in the sandstones and shales above the blanket. Some of them are separated from the latter only by a few inches of crushed shale. But one of the largest masses occurs about 50 feet above the main blanket. An upraise in this mass shows it to be over 40 feet thick, although possibly divided into two or more lenses by layers of shale which were not visible in the timbered upraise. It rests on sandstone and is overlain by soft gray shales impregnated by pyrite. According to Mr. Gladford Smith, who sank the Crebee shaft, three flat bodies of pyrite aggregating over 50 feet in thickness and separated by shales were passed through. The depth of the shaft is 265 feet. The pyrite, which is nearly pure, occurs in loose, sandy form or in solid masses. It is of too low grade to work with the present facilities.

C. H. C. MINE.

This was one of the first mines worked on C. H. C. Hill, and produced considerable ore. The workings, which were relatively extensive, are now abandoned and so little accessible that no description of the mine is possible. The first workings were reached through a shaft, sunk about 300 feet north of the Princeton tunnel, at an altitude of 9,800 feet. The C. H. C. tunnel was subsequently run in about 100 feet lower down the hill, and much work was done on the Limestone tunnel, about 400 feet north of the Mountain Spring tunnel.

The ore occurred in a blanket, probably identical with that worked in the Wellington and Princeton mines.

LOGAN MINE.

This lies immediately north of the Wellington group. The first mining was done through the Logan shaft, sunk at an elevation of 9,950 feet, in a little ravine which appears to mark on the surface the location of the Blackhawk fault, familiarly known on C. H. C. Hill as the "big fissure." A second shaft was sunk about 200 feet lower down this ravine. Both are now abandoned, and the present adit is a tunnel, also in the ravine, entering at an elevation of 9,650 feet, a little above the Pigeon mine.

The accessible portions of the older workings, lying southeast of the Logan shaft, have been already described in connection with the Wellington mine, through which they are at present reached.

The Logan tunnel follows a general southeasterly course, connecting with the Logan No. 2 shaft, and continuing toward the Logan shaft. This course keeps it on the southwest side and nearly parallel to the so-called "big fissure," which is reached by some northeast crosscuts. One of these crosscuts about 100 feet southeast of the Logan No. 2 shaft shows that the "big fissure," which will be referred to as the Pigeon vein, on account of its prominence in the mine of that name, is a large quartz vein, 12 feet wide, consisting of white quartz and masses of crumbling pyrite. It is much broken up, and mingled with gouge and fragments of country rock. The vein dips northeast, apparently at from 45° to 50°. The hanging wall consists of dark, much broken, and partly decomposed shale. That this fissure is a fault of considerable throw is indicated by the cutting off of a dike of white porphyry, as shown in fig. 70. The amount and direction of throw, however, are not known.

The ore in the Logan tunnel occurs in two or more blankets between beds of sandstone and limestone. These present many variations in character. Near the Logan No. 2 shaft the main blanket lies between somewhat shaly, arkose sandstones. It is very irregular in dip, but conforms generally to the bedding of the inclosing rocks. It consists of limonite, either cellular or crumbling, with much soft, nearly white material, which passes with no sharp break into firm sandstone, of which it is plainly an altered form. The sandstone, which in surface exposures is usually greenish in color, is nearly white in the vicinity of the ore bodies, although irregularly streaked with iron oxide. Under the microscope it is seen to be composed chiefly of quartz and sericite. The sericite, in minutely crystalline aggregates, acts partly as a matrix for the quartz grains, and occurs also in patches, probably representing altered fragments of feldspars. Some larger scales of white mica are visible with the unaided eye. Chemical analyses of this sandstone and its alteration product are given on page 287, and the nature of the change which they indicate is there discussed.

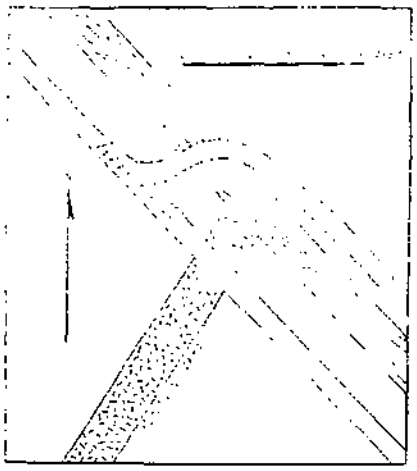


Fig. 70.—Diagram illustrating faulting of a porphyry dike by the Pigeon lode fissure in Logan mine.

Nearer to the Logan shaft the blanket, here from 3 to 4 feet thick, rests on limestone and is overlain by sandstone. The upper part of the blanket is derived from the overlying sandstone through the alteration just noted. The lower portion (a little less than one-half of the whole) is chiefly an ocherous or limonitic mass, which falls to a powder when dry, and is evidently in part formed at the expense of the limestone. It is roughly laminated and is concentric with the irregular upper surface of the underlying limestone. Between the ferruginous material and the limestone is a shell of soft, white material, which adheres to the limestone and constitutes a crust of alteration. This crust is minutely fissured, and the cracks are filled with a soft, black powder, probably manganiferous. The white crust adhering to the limestone is chiefly gypsum, as shown by chemical tests. Closely associated with this crust is another white substance, not at first distinguished from the compact white gypsum. This material proves to be halloysite. The halloysite is intimately associated with the ferruginous material above it, and is full of little specks and nests of soft, black oxide of manganese. The relations of these various materials are diagrammatically shown in fig. 71. The limonite material, especially near the Pigeon vein, is sometimes rich enough to work. Some was said to contain up to 3 ounces of gold and 30 ounces of silver per ton.

It is very probable that the so-called "main contact" of the Logan

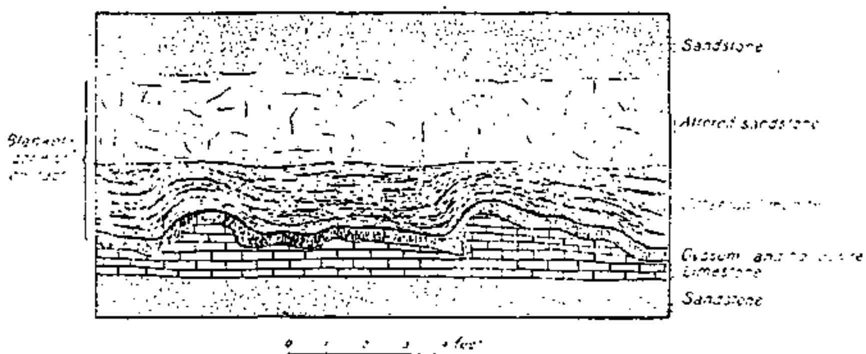


FIG. 71.—Diagrammatic section through a portion of the blanket zone of the Logan mine.

is the same as that worked in the Wellington, C. H. C., and Princeton mines. But it is certain that other similar, but less extensive zones occur in the Logan mine, both above and below the main one. They do not necessarily contain any workable ore. Nearly flat blankets of pyrite are frequently met with on the southwest side of the Pigeon vein, extending from the latter out into the bedding planes. This pyrite is of too low grade to work. At a varying distance from the Pigeon vein, it usually passes into the limonite material already described, which is sometimes valuable as ore.

PIGEON MINE.

This mine, the most northerly of the important workings on C. H. C. Hill, lies northwest of and about 100 feet below the Logan tunnel. It was formerly worked through three tunnels and two shafts. The original Pigeon shaft, at an altitude of about 9,850 feet, lies about 600 feet west of the Logan shaft.

The lowest workings of the Pigeon consist of the Blaine and Logan tunnel, run at an elevation of about 9,300 feet. This penetrates sandstones and shales, which show far less disturbance than is usually found in C. H. C. Hill, and may possibly be in place. No ore has been shipped from this tunnel, although a little replacement ore in limestone was found at the bottom of a winze, 90 feet below the tunnel.

One branch of this lower tunnel cuts through the Pigeon lode, which shows a width of 40 feet. It is composed of several stringers of barren white quartz, separated by sheets of country rock, the whole being crushed and disturbed. The vein strikes about N. 50° W. and dips northeast at 75°. The foot wall is slightly shaly sandstone, decomposed to a soft, gray mass for a width of 3 feet.

Most of the Pigeon ore has come from the upper tunnels, about 200 feet above the Blaine and Logan tunnel. It occurs in a blanket, which, although encountered at a lower level than that of the Logan mine, may yet be identical with the latter. If so, it owes its lower position to faulting connected with landslide movement. The blanket is often 6 feet and sometimes as much as 12 feet. It varies greatly in character. In places it is a breccia of limestone and shale, the former being silicified and impregnated with pyrite. It frequently contains lenticular masses and streaks of crumbling iron pyrite, or bodies of more or less ocherous, limonitic ore. Sometimes there are streaks of soft, banded material resembling that described in the Princeton mine, and sometimes masses of white pulverized quartz (sugar quartz). The blanket is usually underlain by fine-grained sandstone or shale. It is apparently overlain by sandstone, although the roof is not well exposed. The blanket generally dips gently to the southwest, but shows many irregularities. At one point it was found to turn up toward the north at an angle of 55° for about 20 feet and then to resume its usual gentle dip.

The entire blanket shows evidence of much movement, and the inclosing rocks are broken and decomposed. Much work has been done on this ore zone, but apparently without very great success, as most of it contains only low-grade pyrite.

As in the Logan mine, ore is not confined to a single horizon. In what is known as the middle tunnel, a lode striking N. 45° W. is drifted on for some distance. It is probably the Pigeon lode, but is greatly broken and decomposed and not well exposed. Some ore occurred in the bedding planes on the southwest side of this fissure, and carried 8 or 10 ounces of silver and 18 per cent of lead. These were mere local lenses of oxidized ore which did not extend far from the main fissure. A specimen of some of the so-called "carbonate ore," a yellow ocherous powder, proved upon analysis to be chiefly jarosite, a hydrous sulphate of iron and potassium (see p. 289).

LILY D. MINE.

This is situated on the southwestern slope of C. H. C. Hill, the main adit being a tunnel at 9,150 feet in elevation. This tunnel runs N. 85° E. for 220 feet and then connects, through a raise of 80 feet, with some irregular workings exploiting two blankets. These zones, which are about 8 feet apart, have been faulted by a vein striking S. 80° E. and dipping N. 85°. The fissure is filled with crushed rock, quartz, and gouge, and carries no ore. Normal faulting to the extent of 12 feet throw, has taken place along this fissure, but whether before or after the deposition of the blanket ore, is not known.

The blanket contains masses of solid pyrite, cellular quartz, limonite; and streaks of partly oxidized sphalerite and galena ore. The lower blanket rests on sandstone and is overlain by shale. At one place, however, near the fault fissure, it dips southward at an angle of 35° and cuts across some of the bedding planes. The upper blanket lies in a brecciated zone in shale.

The ore contains about 20 per cent of sphalerite and is difficult to treat on that account.

As is usually the case on C. H. C. Hill, all the rocks in the workings are much broken. Their general dip is southerly at about 10°.

IRON GIANT MINE.

This is a prospect lying north of the Lily D. and about 50 feet higher up the hill. It consists of a tunnel about 500 feet in length, running N. 63° E. and cutting through shales and fine-grained, reddish, sandy limestone. These strata, which dip southwest at a slight angle, are all more or less shattered, in the usual manner. Two or more so-called "contacts"—i. e., zones of soft, crushed material, sometimes containing pyrite, are cut in the tunnel. These zones conform to the bedding, but do not preserve their continuity far, being cut off by fractures filled with gouge or crushed rock.

The chief interest of this prospect is derived from the fact that after cutting through nearly 500 feet of the usual disturbed rock of C. H. C. Hill, the tunnel has come into a mass of old surficial gravels, 250 feet vertically below the surface, proving conclusively (were any such proof needed) the landslide character of the material covering C. H. C. Hill. These gravels consist of partially rounded gravel and sand. Some bowlders occur up to 300 pounds in weight, and those a foot in diameter are not uncommon. Most of the material, however, is finer. The small pebbles are usually well rounded, while the larger ones are subangular. The most abundant pebbles are those composed of fine-grained red sandstone; others are of gray sandstone, monzonite, or diorite-porphyry, white quartzose porphyry, shale, white limestone, and quartz. One pebble of galena was found. All of the material is oxidized, and the resulting yellow color is in marked contrast to that of the dark brecciated shales, which overlie the gravels, and contain a few little streaks of ore. The gravel is such as might be expected to accumulate in a steep side gulch rather than in an important stream.

Above the Iron Giant, and belonging to the same group (M. M. P. group) is the old M. M. P. tunnel, now caved in and abandoned. It is said to have produced some ore from a "contact," and to have opened up some large masses of pyrite.

MISCELLANEOUS PROSPECTS.

GENERAL.

Under the heading of "Miscellaneous prospects" will be described a few workings which can scarcely be classed as productive mines, and yet which offer some points of interest in a general treatment of the region. In addition to these, however, there still remain numerous prospects and abandoned workings, detailed accounts of which would possess no general value, and are, therefore, omitted.

ATLANTIC CABLE MINE.

This is an old prospect situated on the northern edge of Rico, in Devonian limestone. With it may naturally be described the Smuggler, Shamrock, and Riverside claims, on the west side of the river. As the ore on these claims outcropped plainly in the banks of the Dolores River and of Silver Creek, they were among the earliest in the district to be exploited. But the ore proved of such low grade and so irregular in its occurrence that work was abandoned, after unsuccessful attempts to concentrate the ore for galena. In 1900 the Atlantic Cable claim was being prospected by shallow shafts, with a view to the extraction of zinc ore.

The ore consists chiefly of sphalerite, chalcopyrite, pyrite, and a little galena, in a dark-green, compact gangue consisting largely of chlorite. With the chlorite, however, is usually associated more or less cryptocrystalline cherty material, in knots or bunches, nests of wollastonite and garnet, and veinlets of epidote. Near the Dolores River, and particularly on the Smuggler and Shamrock claims, the ore changes to masses of specularite and chlorite. The limestone, which constitutes the country rock of the ore, has a curious, blotchy appearance, briefly referred to by Cross and Spencer[1] as due to metamorphism. When a surface of this limestone is examined, patches of white crystalline limestone and areas of chert and of dark-green chlorite are seen to be so disposed as to strongly suggest a breccia structure, the original sharpness of which has been somewhat obscured by later metamorphism. It is believed that the hypothesis thus suggested best explains this peculiar spotted appearance. The limestone, originally impure, and situated in the heart of the Rico uplift, was brecciated, the brecciation apparently involving some layers of shale which are exposed in less disturbed condition in the bottom of what is known as the Gas shaft, on the Job Cooper claim, which adjoins the Atlantic Cable on the east. After brecciation, the limestone was metamorphosed, possibly as Cross and Spencer[2] suggest, by the intrusion of the monzonite between Aztec Gulch and Iron Draw. As a result of this metamorphism, the fragments of limestone recrystallized as pure white marble,

[1] Loc. cit., p. 45.

[2] Loc. cit., p. 46.

in some cases separated from cherty fragments by reaction rims of epidote, garnet, and wollastonite, the shale was chloritized, and more or less garnet, wollastonite, chlorite, and epidote were developed in bunches and streaks throughout the mass. It is impossible to distinguish here between this metamorphism and the ore-deposition. The two processes went on together, as shown by the close association of the sphalerite, specularite, chalcopyrite, galena, and pyrite, with the chlorite, and the frequent bunchy or knot-like occurrence of these ores.

Although some of the ore masses have a thickness of 25 feet, and contain excellent zinc ore (up to 30 per cent of zinc), their erratic occurrence has so far baffled attempts at systematic exploitation. They sometimes extend irregularly into the white limestone, dying out in small stringers and bunches. In other directions they grade into masses of specularite and chlorite or stop abruptly at some fracture plane containing a slight seam of gouge. No particular regularity of trend is noticeable in these fractures, nor is it certain that they are to any extent fault fissures. They appear rather to be fractures that originally partly controlled the deposition of the ore.

IRON DOLLAR AND EIGHTY-EIGHT MINES.

The Iron Dollar shaft is sunk in the bed of Silver Creek, about half a mile from the mouth of this stream. The workings are abandoned and full of water. The dump shows quantities of pyrite, specularite, and quartz, with some chalcopyrite. Chlorite, epidote, and calcite are also abundant, indicating that the deposit is mineralogically similar to that of the Atlantic Cable. The Eighty-Eight shaft, about 150 feet north of the Iron Dollar, shows a dump of similar character.

About 150 feet west of the Iron Dollar shaft a tunnel about 225 feet in length has been run into the hill in a direction N. 30° E. This tunnel cuts a lode, which is probably the one formerly worked in the now inaccessible Eighty-Eight shaft. The lode strikes N. 85° W. and dips N. at 85°. It is rather irregular and in places consists of several stringers of nearly barren quartz in Lower Hermosa shales. The latter, for a distance of 4 or 5 feet on each side of the lode, are much altered, and locally transformed to a mass of specularite, pyrite, chlorite, and other minerals, in the mineralogical association so characteristic of the Atlantic Cable group of claims. In this case, however, the metamorphism occurs in Lower Hermosa shales, the underlying Ouray limestone being not exposed, and it is plainly connected with lode fissures. This connection, and the general east-west trend of the lode, suggests that the latter or some generally parallel fissures may have been instrumental in effecting the ore deposition of the Atlantic Cable. The occurrence is particularly interesting in showing that the specularite and chlorite may form by metasomatic replacement of the shales alongside of a lode fissure.

BURNS MINES.

These are prospects situated on both sides of the river at Burns station, in Lower Hermosa beds. The A. B. G., on the west side of the stream, is developed by tunnels run in on a large northwesterly lode, showing an average width of about 4 feet. The strike of the lode varies from N. 20° W. to N. 45° W. It dips northeast at about 85°. The fissure is occupied by a rather irregular vein containing galena, sphalerite, and pyrite in a gangue of quartz and calcite, and accompanied by much soft gouge on both walls. The ore is low in grade and has not yet been profitably worked.

On the southwest side of the lode, and probably connecting with it, is a blanket deposit, with a northerly dip of 10°. This consists of a layer of partly oxidized, crumbling pyrite, about a foot in thickness, underlain by limestone and overlain by calcareous shale. The ore is separated from the overlying shale by a gouge, and the shales themselves are partly decomposed to clay. In the northwest part of the blanket workings a bed of limestone appears between the ore and overlying shale and attains a maximum thickness of 2 feet. On the southeast this limestone thins, softens, and passes into gouge.

Some ore has been mined from this blanket, and is said to carry from 35 to 40 ounces of silver and $4 in gold per ton, and from 4 to 6 per cent of copper.

On the east side of the river is the C. V. G., a prospect which is probably on the Pigeon lode. The workings had caved near the tunnel mouth in 1900 and were inaccessible. The lode is said to be 40 feet wide and to contain quartz and pyrite.